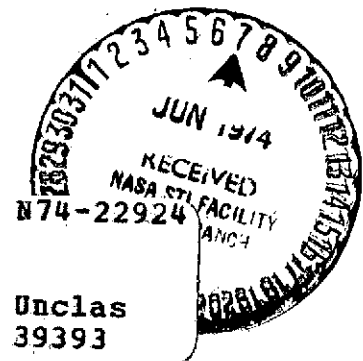




(NASA-CR-132439) MANUAL FOR SOURCE FLOW
CHARACTERISTICS PROGRAM (Advanced
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ATL TM 179

MANUAL FOR SOURCE FLOW
CHARACTERISTICS PROGRAM

By

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- UNDER

CONTRACT NAS1-12104

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TM 179
SECTION I
INTRODUCTION

The FØRTRAN IV program described herein analyzes the nozzle for a hypersonic scramjet by a two dimensional second order characteristic procedure described in ATL TR 186, "A Source Flow Characteristic Technique for the Analysis of Scramjet Exhaust Flow Fields."

The program starts from the initial profile and marches along down-running characteristics until the final X station is reached. This process can be interrupted by "Change of Origin Profiles" in source flow cases. This is done by interpolating the characteristic data at the required axial station and setting up "F a-rays" i.e., XF, YF, Then the program continues on down-running characteristics using the "F arrays" as an initial profile. These "F arrays" are computed for all flows at an X station that coincides with the cowl tip if there is a cowl in the flow field. If the flow is overexpanded at the cowl the program will invert the problem as described in ATL TR 186. When the shock reflects off the lower wall "F arrays" are again calculated and the computation continues with the problem inverted again until the final axial (X) station is attained.

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SECTION II
DESCRIPTION OF INPUT

A. Input Format

<u>Card Number</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
1	1-5	15	J1, type of flow (0-two dimensional, 1-axisymmetric)
	6-10	15	J2, coordinate exponent for line source system (0-two dimensional or axisymmetric, 1-line source)
	11-15	15	NPTS, number of data points on initial profile
	16-20	15	IEQ, chemistry indicator (0-frozen hydrogen-air chemistry, 1-equilibrium chemistry) NOTE: If ICØWL = 1 then IEQ = 1.
	21-25	15	ICØWL, external data indicator (1-overexpansion or underexpansion interaction calculations is required, 0-internal flow only). If IEQ = 0 then ICØWL = 0.
	26-30	15	IØVER, overexpansion indicator (0-flow definitely underexpanded, 1-flow overexpanded or marginal)
2	1-10	E10.0	*XBP, ratio of axial coordinate of cowl at initial station to throat height
	11-20	E10.0	XBØD, ratio of axial coordinate of lower wall at initial station to throat height
	21-30	E10.0	XCØWL, ratio of axial coordinate of cowl trailing edge to throat height
	31-40	E10.0	RTH, throat height (ft.), scaling parameter L*
	41-50	E10.0	TEST, maximum allowable axial step size, used for computing upper boundary - typical value = .1

*(All length variables are nondimensionalized by RTH.)

<u>Card Number</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
2	51-60	E10.0	XFINAL, ratio of final axial coordinate of run to throat height
	61-70	E10.0	XTJ1, ratio of axial coordinate of beginning of Cartesian region to throat height
3	1-10	E10.0	XSHFT, ratio of axial coordinate of moment axis to throat height
	11-20	E10.0	YSHFT, ratio of radial coordinate of moment axis to throat height
	21-30	E10.0	XTHX, initial thrust (lbs/RTH ²)
	31-40	E10.0	YLFT, initial lift (lbs/RTH ²)
4	1-5	15	NXXJ1, number of locations in source flow where a new initial profile is desired, maximum is 4, minimum is 1 (i.e. changes of origin, cowl station,...)
5	One of the following cards is necessary for each NXXJ1. If NXXJ1 equals 1 and 2-D flow, card 5a may be blank.		
5a	1-10	E10.0	XXJ1, ratio of axial coordinate of new initial profile to throat height
	11-20	E10.0	AXX, coefficients of polynomial describing a segment of lateral extent of the nozzle
	21-30	E10.0	BXX, for the equation $Z_L = AXX(X-X_1) + BXX$
	31-40	E10.0	XOR, ratio of axial coordinate of line source origin
5b	1-5	15	IFENCE, fence indicator (0-no fence; 1-supersonic fence exists)
	11-20	E10.0	AFENCE, coefficients of fence for the equation
	21-30	E10.0	BFENCE, $Y=AFENCE(X-XBP) + BFENCE$
	31-40	E10.0	XFENCE, ratio of axial coordinate of fence on lower surface to throat radius
6	1-5	15	NUWSEG, number of polynomial segments describing the cowl (maximum is 3)
	6-10	15	NLWSEG, number of polynomial segments describing the lower wall (maximum is 3).

<u>Card Number</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
7	One of the following cards is necessary for each cowl segment.		
7A	1-10	E10.0	XXU(L), ratio of axial coordinate of beginning of "L th " segment of cowl to throat height
	11-20	E10.0	A, coefficients of the "L th " segment
	21-30	E10.0	B, of polynomial describing cowl for the equation
	31-40	E10.0	C, $Y=AX^2+BX+C$; $Y=Y/RTH$ & $X=X/RTH$
8	One of the following cards is necessary for each lower wall segment.		
8a	1-10	E10.0	XXL(L), ratio of axial coordinate of beginning of "L th " segment of lower wall to throat height
	11-20	E10.0	A, coefficients of the "L th " segment
	21-30	E10.0	B, of polynomial describing lower wall for the equation
	31-40	E10.0	C, $Y=AX^2+BX+C$; $Y=Y/RTH$ & $X=X/RTH$
9	1-10	E10.0	EMINF, free stream or reference Mach number
	11-20	E10.0	TIN, free stream or reference temperature (⁰ K)
	21-30	E10.0	WINF, free stream or reference molecular weight (lbs/lb-mole)
	31-40	E10.0	PINF, free stream or reference pressure (lbs/in ²)
10	Initial Profile - One of the following cards are required for each data point as described below. The program reads data points beginning at the lower wall (point #1) and proceeds to the cowl (point #NPTS).		
10a	1-10	E10.0	X(I), ratio of axial coordinate of data point to throat height
	11-20	E10.0	Y(I), ratio of radial coordinate of data point to throat height
	21-30	E10.0	P(I), ratio of pressure at data point to free stream pressure
	31-40	E10.0	Q(I), ratio of velocity at data point to free stream velocity

<u>Card Number</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
	41-50	E10.0	T(1), ratio of temperature at data point to free stream temperature
	51-60	E10.0	TH(1), flow inclination at data point (in radians)
	61-70	E10.0	R(1), fuel to air equivalence ratio (only necessary if IEQ=1)
11	Initial Mass Fractions - Same as card 10 above except for mass fractions at each data point. These cards are necessary only if IEQ=0.		
11a	1-10	E10.0	mass fraction of H
	11-20	E10.0	mass fraction of O
	21-30	E10.0	mass fraction of H ₂ O
	31-40	E10.0	mass fraction of H ₂
	41-50	E10.0	mass fraction of O ₂
	51-60	E10.0	mass fraction of OH
	61-70	E10.0	mass fraction of N ₂
12	This card is necessary only if ICOWL=1.		
	1-5	15	MM, number of points in Prandtl-Meyer fan including data downstream of shock (MM=9)
	11-20	E10.0	PM, ratio of pressure external to the cowl to free stream or reference pressure
	21-30	E10.0	QM, ratio of velocity external to the cowl to free stream or reference velocity
	31-40	E10.0	TM, ratio of temperature external to the cowl to free stream or reference temperature
	41-50	E10.0	THM, flow inclination external to the cowl (in radians)
	51-60	E10.0	RM, fuel to air ratio external to the cowl (only needed if IEQ=1)

B. Figures for Input

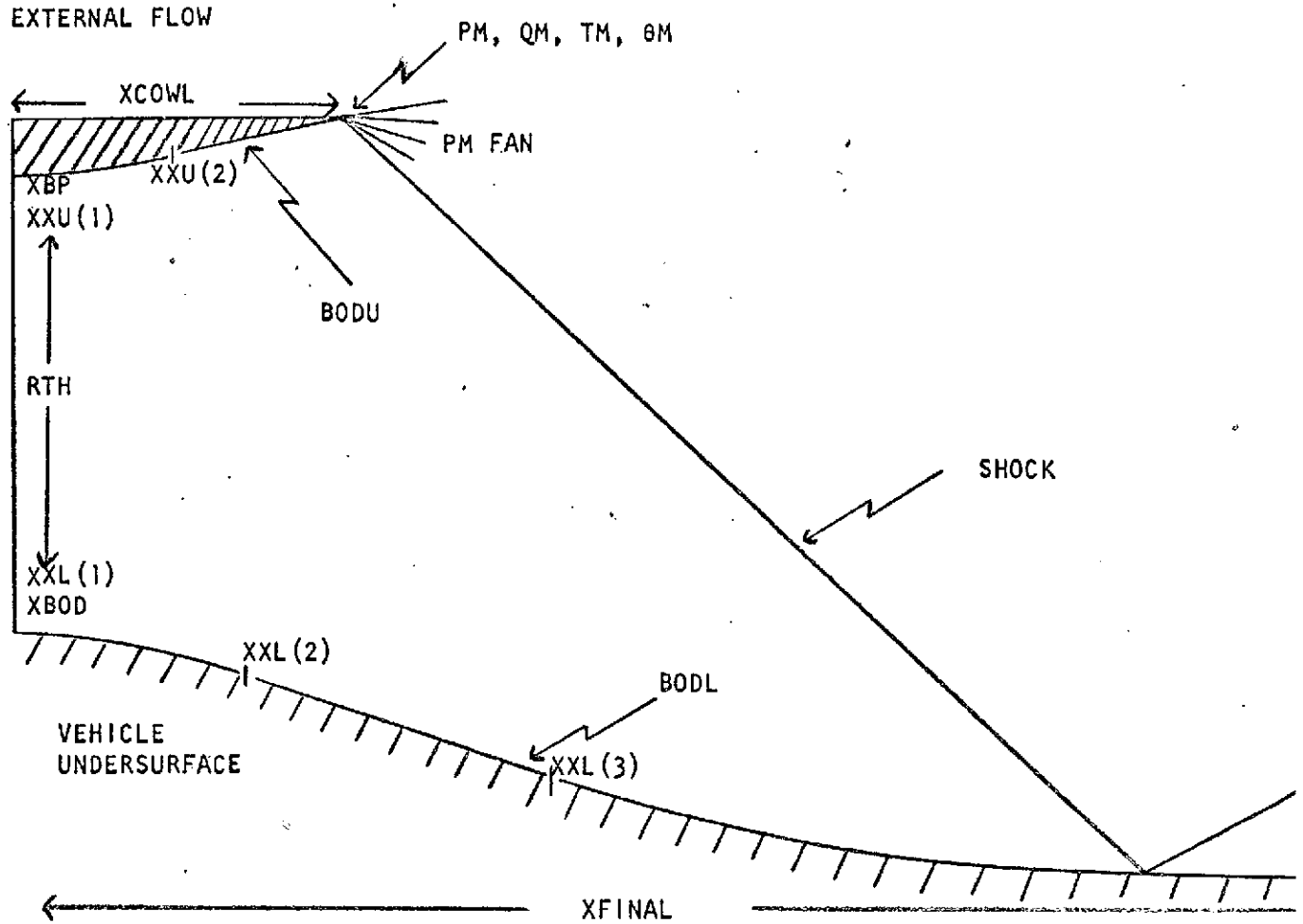


FIGURE #1. Definition of Physical Input Variables

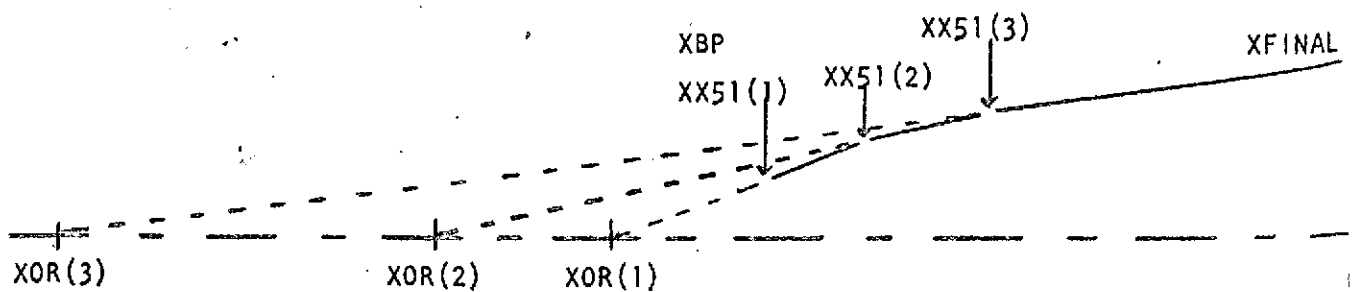


FIGURE #2. Definition of Change of Origin Variables

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SECTION 111

DESCRIPTION OF OUTPUT

A. Output Format - The heading page contains program constants, line source coordinates and origin changes, upper and lower wall coordinates, free stream data at the cowl and infinity conditions. The program then prints the "initial profile," the data at selected points along down-running characteristics in the flow field and the running lift, thrust and pitching moment. The process continues until the input value for the final axial location is reached.

The above flow can be interrupted by "change of origin profiles" and a profile at the trailing edge of the cowl. If the flow is over-expanded at the cowl the output will switch to up-running characteristics from the lower wall to the contact surface and additional output covering the shock angle and external Mach number will be printed. When the shock reflects off the lower wall another profile will be printed and the run will proceed to the final axial location through down-running characteristics.

B. Identification of Output Variables

X - axial distance/throat height
Y - radial distance/throat height
Q - velocity/free stream velocity
T - temperature/free stream temperature
P - pressure/free stream pressure
TH - flow angle (radians)
EM - Mach number

ALP(1) = mass fraction of H
ALP(2) = mass fraction of O
ALP(3) = mass fraction of H_2O
ALP(4) = mass fraction of H_2
ALP(5) = mass fraction of O_2
ALP(6) = mass fraction of OH
ALP(7) = mass fraction of N_2

Frozen flow extra output is:

CPX - specific heat/free stream specific heat

W - molecular weight of mixture/free stream molecular weight

Equilibrium flow extra output is:

GAM - equilibrium isentropic exponent

PHI - fuel to air ratio

SECTION IV

SUBROUTINES AND FUNCTIONSA. Subroutines

<u>Name</u>	<u>Description</u>
1. INDATA	reads and prints initial data and computes infinity conditions
2. COEFF	sets thermodynamic coefficients as functions of temperature
3. ERROR	prints program statement number nearest selected errors and terminates computer run
4. BODL	locates axial and radial coordinates along lower vehicle surface
5. BODU	locates axial and radial coordinates along upper cowl surface
6. COWL	calculates shock jump relations and Prandtl-Meyer fan at cowl trailing edge for under-expanded flow
7. COWLO	computes contact points, shock points and shock angle at cowl trailing edge for over-expanded flow
8. SHOCK	calculates shock jump conditions
9. SHOCPT	computes shock angle by matching pressure from shock jump relations and pressure from characteristic relation on downstream side of shock
10. PANDW	makes pressure and frozen chemistry molecular weight or equilibrium chemistry fuel to air ratio
11. DRTEST	tests for dropping data points on free stream side of shock
12. PM	computes isentropic air expansion
13. ALL	calculates density, ratio of specific heats, Mach number, Mach angle, frozen flow specific heat, molecular weight and gas constant
14. THERMO	computes frozen flow specific heat, derivative of specific heat and enthalpy of each species from polynomial fits in temperature
15. XMASSS	computes mass flow correction factor
16. FM	computes mass function
17. PM1	computes flow properties for given Prandtl-Meyer turning

B. Functions

<u>Name</u>	<u>Description</u>
1. FT	calculates temperature at any data point in flow field
2. FH	computes static enthalpy at any point in flow field
3. FGAM	makes isentropic exponent and associated thermodynamic data at any point in flow field
4. RHEQ	computes equilibrium density
5. XM1	calculates $\tan(\theta + \mu)$ along up-running characteristic
6. XM2	calculates $\tan(\theta - \mu)$ along down-running characteristic
7. XM3	calculates $\tan(\theta)$ along streamline
8. F1	*A ₁ or B ₁ coefficient along up-running and down-running characteristics respectively
9. F2	*A ₂ or B ₂ coefficient along up-running and down-running characteristics respectively.

*Note: $p - \theta$ relationship along up-running characteristic:

$$A_1(p_C - p_A) + \theta_C - \theta_A + A_2(X_C - X_A) = 0$$

$p - \theta$ relationship along down-running characteristic:

$$B_1(p_C - p_B) - \theta_C + \theta_B + B_2(X_C - X_B) = 0$$

SECTION V.

MACHINE CONTROL CONSIDERATIONS

1. Machine - program designed for CDC 6600.
2. Estimates for run.
 - a. Field length:
 - (1) compile - 65,000 octal locations
 - (2) load - 120,000 octal locations
 - (3) run - 100,000 octal locations
 - b. CP time: variable depending on number of points in initial profile and type of flow
 - c. IO: less than 100 octal seconds
 - d. Tapes or disks used:
 - (1) Tape 5 - card input
 - (2) Tape 6 - printed output
 - (3) no other tapes or disk files used
 - e. Printed output: as in CP time it is variable depending on case submitted.

0.	0.	1.	41	1.	1.	0.	1.	.1	21.	22.
0.	0.	0.	0.	3.	0.	0.	0.	0.	0.	0.
0.	2	0.0875	1.	0.	0.	0.	0.	0.	0.	0.
3.	0.0875	1.	0.	0.	0.	0.	0.	0.	0.	0.
1	0.59	3.064	16.	0.	0.	0.	0.	0.	0.	0.
2	3	0.1314	0.	1.	0.	0.	0.	0.	0.	0.
0.4	0.	0.1051	0.979	0.	0.	0.	0.	0.	0.	0.
0.	0.5565	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.4	0.	0.4452	0.08905	0.	0.	0.	0.	0.	0.	0.
8.	0.01019	0.6082	0.741	0.	0.	0.	0.	0.	0.	0.
10.	232.3	28.96	0.1603	0.	0.	0.	0.	0.	0.	0.
0.	0.	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.025	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.05	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.075	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.1	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.125	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.15	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.175	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.2	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.225	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.25	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.275	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.3	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.325	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.35	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.375	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.4	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.425	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.45	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.475	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.5	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.525	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.55	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.575	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.6	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.625	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.65	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.675	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.7	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.725	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.75	36.65	0.929	10.1	0.	1.	0.	1.	0.	1.
0.	0.775	36.65</								

APPENDIX

PROGRAM LISTING

The following is a listing of the Fortran IV program for Source Flow
Characteristic


```

PROGRAM NOZ BOD (INPUT,OUTPUT,PUNCH,TAPE5=INPUT,TAPE6=OUTPUT,
1 TAPE7=PUNCH)
COMMON/COWL/ICOWL,MM,XM(9),YM(9),PMM(9),WM(9),RHM(9),THM(9),QM(9),
1RM(9),TM(9),GM(9),XMUM(9),EMM(9),ALPM(7,9),CPXM(9)
COMMON/IPP/IPP
COMMON/SHAPE/AA1(3,2),AA2(3,2),AA3(3,2),XXU(3),XXL(3),XINTU,XINTL
COMMON/LTM/XSHFT,YSHFT,XTHX,YLFT,XMDM
COMMON/XXJ/NXXJ1,XXJ1(6),AXX(6),BXX(6),XOR(6)
COMMON/XFINAL/XFINAL
COMMON/IEQ/IEQ,PIN,RHONF,UINF,PINF
COMMON/VAR/RHO(200),
1EM(200),XMU(200),CPX(200),W(200),R(200),GAM(200),XMASS(200),
2 XN(200),YN(200),QN(200),TN(200),PN(200),THN(200),RHON
3(200),EMN(200),XMUN(200),CPXN(200),WN(200),RN(200),GAMN(200),
4XMASSN(200),ALPN(10,200),SI(10),HI(10), ERR(20),TEMP(20)
5,ALPDUM(10)
COMMON/SP/NSP
COMMON/FVAR/
1RHO(200),CPXF(200),EMF(200),XMUF(200),WF(200),RF(200),GAMF(200),
2XMASSF(200), HF(200),SF(200),ALPD(10),
3THETA(20)
COMMON/X/X(200),Y(200),P(200),Q(200),T(200),TH(200),ALP(10,200)
COMMON/I/IOPUT
COMMON/A/TIN,CPIN,R0
COMMON/B/WTMOLE
COMMON/D/GAMINF,EMINF,RINF,WINF
COMMON/F/A9,B9,IBOD,XWF,NBOD,YEND
COMMON/ETX/XJ,XJ1,NPTS,IO,IREFL,ICHEM,IPUNCH,IDESGN,IR,NXX,XBP,
1YBP,THBP,RAD,XBOD,YBOD,THBOD,RADB,XEND,THEND,RTH,YEXIT,THST,TEST,
1IREFL,YO,RADB2,RRAD(20), NSTAR,YNOZ,EIN, PEN,H16,H17
COMMON/XF/XF(200),YF(200),PF(200),QF(200),TF(200),THF(200),ALPF(
110,200)
COMMON/XCOWL/XCOWL
COMMON/ZC1Z EMC1,TC1,QC1
COMMON/IOVER/IOVER
COMMON/XTJ1/XTJ1
COMMON/FENCE/IFENCE,AFENCE,BFENCE,XFENCE
DIMENSION WTMOLE(10)
DIMENSION ERAD(20)
DIMENSION TYPE2(2)
DIMENSION TYPE3(2)
DIMENSION TYPE9(2),PHIPR(2)
DATA PHIPR/3H ,3HPI/
DATA TYPE9/3HCPX,3HPI/
DATA TYPE3/3HW ,3HGAM/
DATA TYPE2/10H NOZZLE ,10HCENTERBODY/
DATA XXP/1.E+06/
DATA ISHOC/-10000/
WRITE(6,400)
400 FORMAT(1H1)
J=0 TWO DIMENSIONAL
J=1 AXISYMMETRIC
SPECIES 1 IS H
SPECIES 2 IS O
SPECIES 3 IS H2O
SPECIES 4 IS H2
SPECIES 5 IS O2
SPECIES 6 IS OH
SPECIES 7 IS N2
SPECIES 8 IS CO2

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```

C SPECIES 9 IS CO
C SPECIES 10 IS C3H8
IPTP=0
NXXJ=2
IFLIP=0
IHALT=0
ICMPLT=0
NSTAR=0
IOPUT=32
IEXIT=0
IAA=1
CALL INDATA
XCOWLH=XCOWL
IEQ5=IEQ+1
YNOZ=YBP
PEN= PIN
XJ1SV=XJ1
PFINF=PINF*144./PIN
IFENC1=0
7211 IPP=0
LSTT=0
WRITE(6,400)
IF (IFENC1.EQ.1) WRITE(6,3100)
3100 FORMAT(30X*FENCE INITIAL PROFILE*)
IF (IFENC1.EQ.1) GO TO 3101
IF (IPTP.EQ.0) WRITE(6,9191) XOR(1)
9191 FORMAT(20X*INITIAL PROFILE*
1* - ORIGIN OF SYSTEM =*E13.5)
IF (IFLIP.EQ.0.AND.IPTP.EQ.1.AND.XF(1).NE.XCOWLH) WRITE(6,9192)
1 XOR(NXXJ-1)
9192 FORMAT(16X*CHANGE OF ORIGIN PROFILE*
1* - ORIGIN OF SYSTEM =*E13.5)
IF (IFLIP.EQ.0.AND.IPTP.EQ.1.AND.XF(1).EQ.XCOWLH) WRITE(6,3132)
1 XOR(NXXJ-1)
3132 FORMAT(8X*PROFILE FOR UNDEREXPANDED SHOCK AT COWL*
1* - ORIGIN OF SYSTEM =*E13.5)
IF (IFLIP.EQ.1) WRITE(6,600) XOR(NXXJ-1)
600 FORMAT(8X*PROFILE FOR OVEREXPANDED SHOCK AT COWL*
1* - ORIGIN OF SYSTEM =*E13.5)
IF (IFLIP.EQ.2) WRITE(6,621) XOR(NXXJ-1)
621 FORMAT(6X*PROFILE WHEN SHOCK REFLECTS OFF LOWER WALL*
1* - ORIGIN OF SYSTEM =*E13.5)
3101 CONTINUE
IEQ1=IEQ+1
WRITE(6,6896) PHIPR(IEQ1)
6896 FORMAT( //5X,*PT.*,8
1X,*X*,11X,*Y*,11X,*Q*,11X,*T*,11X,*P*,10X,*TH*10XA3)
IF (ICHEM.EQ.0.AND.IEQ.EQ.0) WRITE(6,7701)
7701 FORMAT(13X*ALP(1)=H*4X*ALP(2)=O*3X*ALP(3)=H2O*2X*ALP(4)=H2*
13X*ALP(5)=O2*3X*ALP(6)=OH*3X*ALP(7)=N2*)
KSIDE=0
IND13=0
3160 CONTINUE
FX2=0.
XLY2=0.
XMOM2=0.
XMAS22=0.
DO 6897 I=1,NPTS
YFPR1=YFPR
THFPR1=THFPR

```

```

YFPR=YF(1)
THFPR=THF(1)
IF(IFLIP.EQ.1) YFPR=-YF(1)
IF(IFLIP.EQ.1) THFPR=-THF(1)
IF(XJ1SV.EQ.0.) GO TO 3102
IF(IPTP.EQ.0) GO TO 3103
IF(XF(1).EQ.XCOWLH) GO TO 3103
IF(IFENC1.EQ.1) GO TO 3103
GO TO 3102
3103 DO 3111 J=1,NSP
3111 ALPDUM(J)=ALPF(J,1)
CALL ALL(CPXF(I),WF(I),RHOF(I),RF(I),GAMF(I),EMF(I),XMUF(I),
10F(I),TF(I),PF(I),ALPDUM)
IF(I.EQ.1) GO TO 3102
JQ=I-1
DY13=YFPR-YFPR1
DX13=XF(1)-XF(JQ)
THS13=1.5707963
IF(DX13.GT.1.E-10) THS13=ATAN(DY13/DX13)
Z1=AXX(NXXJ-1)*(XF(JQ)-XBP)+BXX(NXXJ-1)
Z2=AXX(NXXJ-1)*(XF(I)-XBP)+BXX(NXXJ-1)
XBAR13=(XF(I)+XF(JQ))/2.-XSHFT
YBAR13=(YF(I)+YF(JQ))/2.-YSHFT
E1=GAMF(JQ)*PF(JQ)*EMF(JQ)*EMF(JQ)*SIN(THS13-THFPR1)/SIN(THS13)
E2=GAMF(I)*PF(I)*EMF(I)*EMF(I)*SIN(THS13-THFPR)/SIN(THS13)
F1=(E1*COS(THFPR1)+(PF(JQ)-PIN))
F2=(E2*COS(THFPR)+(PF(I)-PIN))
E11=RHOF(JQ)*QF(JQ)*SIN(THS13-THFPR1)/SIN(THS13)
E22=RHOF(I)*QF(I)*SIN(THS13-THFPR)/SIN(THS13)
ZBAR=(Z1+Z2)/2.
XMS13=(E11+E22)*DY13/2.*ZBAR
XMAS22=XMAS22+XMS13
FFX2=(F1+F2)/2.*DY13*PFINF*ZBAR
COTTHS=COS(THS13)/SIN(THS13)
XLLY1=(E1*SIN(THFPR1)+(PF(JQ)-PIN)*COTTHS)
XLLY2=(E2*SIN(THFPR)+(PF(I)-PIN)*COTTHS)
XXLY2=(XLLY1+XLLY2)/2.*DY13*PFINF*ZBAR
XMOM2=XMOM2+FFX2*YBAR13-XXLY2*XBAR13
FX2=FX2+FFX2
XLY2=XLY2+XXLY2
IF(I.LT.NPTS) GO TO 3102
IF(IPTP.NE.0) GO TO 3105
FX1=FX2
XLY1=XLY2
XMOM1=XMOM2
XMAS12=XMAS22
GO TO 3102
3105 IF(IFENC1.EQ.1) GO TO 3106
IF(XF(I).NE.XCOWLH) GO TO 3102
3106 XTHXMS=FX2-FX1-XTHX
XMOMMS=XMOM2-XMOM1-XMOM
RATM=XMAS22/XMAS12
EMS=RATM-1.
IF(ABS(EMS).LT:1.E-03) GO TO 3161
IND13=IND13+1
IF(IND13.GT.1) GO TO 3161
CALL XMASSS(RATM,NPTS)
GO TO 3160
3161 CONTINUE
KSIDE=1

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3102 CONTINUE
6897 CONTINUE
DO 3163 I=1,NPTS
C=PF(I)/PIN
YFPR=YF(I)
THFPR=THF(I)
IF (IFLIP.EQ.1) YFPR=-YF(I)
IF (IFLIP.EQ.1) THFPR=-THF(I)
IF (IEQ.EQ.1) GO TO 9806
WRITE(6,16) I,XF(I),YFPR,QF(I),TF(I),C,THFPR
      WRITE(6,1602) (ALPF(J,I),J=1,NSP)
GO TO 3163
9806 WRITE(6,16) I,XF(I),YFPR,QF(I),TF(I),C,THFPR,RF(I)
3163 CONTINUE
1800 FORMAT(* UNDERSURFACE AND COWL THRUST =*E13.5,7X*LIFT =*E13.5,7X*M
10MENT =*E13.5)
IPTP=1
XJ1SV=XJ1
WRITE(6,3130)
3130 FORMAT(/)
IF (KSIDE.EQ.0) GO TO 3104
WRITE(6,1800) XTHX,YLFT,XMOM
WRITE(6,3107) XTHXMS,XMOMS
3107 FORMAT(5X*SIDEWALL THRUST =*E12.4,5X*SIDEWALL MOMENT =*E12.4//)
3104 CONTINUE
N=2
LMAX=1
KMAX=2*(N-1)-1
IF (IOVER.NE.2) GO TO 7423
N=3
IPP=1
LMAX=2
KMAX=2
7423 NN1=N-1
DO 7424 I=1,NN1
II=NN1-I+1
X(I)=XF(II)
Y(I)=YF(II)
Q(I)=QF(II)
T(I)=TF(II)
P(I)=PF(II)
TH(I)=THF(II)
W(I)=WF(II)
R(I)=RF(II)
DO 505 J=1,NSP
505 ALP(J,I)=ALPF(J,II)
DO 1500 J=1,NSP
1500 ALPDUM(J)=ALP(J,I)
CALL ALL(CPX(I),W(I),RHO(I),R(I),GAM(I),EM(I),XMU(I),Q(I),T(I),
1P(I),ALPDUM)
7424 CONTINUE
500 CONTINUE
IF (KMAX.GE.191) GO TO 9123
6060 IPP=IPP+1
6883 WRITE(6,7633) IPP
7633 FORMAT(5X,*LINE NO. =*,I4)
IF (IOVER.EQ.2.AND.KMAX.GE.10) GO TO 670
JJ=1+KMAX/10
JJ1=KMAX-1
IF (IO.EQ.1) JJ=1

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WRITE(6,6885)TYPE3(IEQ5),TYPE9(IEQ5)
16 FORMAT(3X,14,3X,10E12.4)
6885 FORMAT(5X,*PT.*,8X,*X*,11X,*Y*,11X,*P*,10X,*TH*,11X,*Q*,11X,*T*,
110X,*EM*,10X,A3,9X,A3)
DO 7637 I=1,JJ1,JJ
C=P(I)/PIN
YFPR=Y(I)
THFPR=TH(I)
DUPR=W(I)
IF(IEQ5.EQ.2) DUPR=GAM(I)
CPR=CPX(I)
IF(IEQ.EQ.1) CPR=R(I)
IF(IFLIP.EQ.1) YFPR=-Y(I)
IF(IFLIP.EQ.1) THFPR=-TH(I)
WRITE(6,7632) I,X(I),YFPR,C,THFPR,Q(I),T(I),EM(I),DUPR,CPR
7632 FORMAT(3X,14,3X,10E12.4)
7637 CONTINUE
1602 FORMAT(10X,10E12.4)
IF(IPP.EQ.1) GO TO 7759
I=KMAX
C=P(I)/PIN
YFPR=Y(I)
THFPR=TH(I)
DUPR=W(I)
IF(IEQ5.EQ.2) DUPR=GAM(I)
CPR=CPX(I)
IF(IEQ.EQ.1) CPR=R(I)
IF(IFLIP.EQ.1) YFPR=-Y(I)
IF(IFLIP.EQ.1) THFPR=-TH(I)
WRITE(6,7632) I,X(I),YFPR,C,THFPR,Q(I),T(I),EM(I),DUPR,CPR
GO TO 7759
670 JJ=1+KMAX/10
JJ2=1
ISH=ISH0C
JJ1=ISH-1
WRITE(6,6885)TYPE3(IEQ5)
672 DO 671 I=JJ2,JJ1,JJ
C=P(I)/PIN
YFPR=Y(I)
THFPR=TH(I)
DUPR=W(I)
IF(IEQ5.EQ.2) DUPR=GAM(I)
CPR=CPX(I)
IF(IEQ.EQ.1) CPR=R(I)
IF(IFLIP.EQ.1) YFPR=-Y(I)
IF(IFLIP.EQ.1) THFPR=-TH(I)
WRITE(6,7632) I,X(I),YFPR,C,THFPR,Q(I),T(I),EM(I),DUPR,CPR
671 CONTINUE
I=JJ1+1
C=P(I)/PIN
YFPR=Y(I)
THFPR=TH(I)
DUPR=W(I)
IF(IEQ5.EQ.2) DUPR=GAM(I)
CPR=CPX(I)
IF(IEQ.EQ.1) CPR=R(I)
IF(IFLIP.EQ.1) YFPR=-Y(I)
IF(IFLIP.EQ.1) THFPR=-TH(I)
WRITE(6,7632) I,X(I),YFPR,C,THFPR,Q(I),T(I),EM(I),DUPR,CPR
IF(JJ1.EQ.KMAX-1) GO TO 7759

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JJ2=ISH+1
JJ1=KMAX-1
GO TO 672
7759 BETPR=BET
WRITE(6,1800) XTHX,YLFT,XMOM
IF(IFLIP.EQ.1) BETPR=-BET
IF(IOVER.EQ.2) WRITE(6,653) BETPR,EMC1
653 FORMAT(5X*SHOCK ANGLE =*E12.4,5X*EXTERNAL MACH NO. =*E12.4)
WRITE(6,1603)
1603 FORMAT(///)
6884 ICMP=ICMPLT+1
IF(IOVER.NE.2) GO TO 2658
ISHOC=ISHOC+1
IF(NSTAR.EQ.1) ISHOC=ISHOC-2
2658 CONTINUE
IF(IHALT.EQ.1) STOP
IF(IFLIP.EQ.2.AND.N.GT.NPTS) STOP
GO TO (4300,4301,4302,4303),ICMP
4301 IF(ICOWL.EQ.0) STOP
ICMPLT=2
CALL COWL(-1.)
IPM=1
4302 IPM=IPM+1
IF(IPM.GT.MM-3) GO TO 4303
LMAX=KMAX+1
X N(1)=X M(IPM)
Y N(1)=Y M(IPM)
P N(1)=P MM(IPM)
W N(1)=W M(IPM)
Q N(1)=Q M(IPM)
R N(1)=R M(IPM)
T N(1)=T M(IPM)
TH N(1)=TH M(IPM)
EM N(1)=EM M(IPM)
RHON(1)=RH M(IPM)
GAMN(1)=G M(IPM)
XMUN(1)=XMUM(IPM)
CPXN(1)=0.
IF(IEQ.EQ.0) CPXN(1)=CPXM(IPM)
DO 4304 J=1,NSP
ALPN(J,1)=0.
4304 IF(IEQ.EQ.0) ALPN(J,1)=ALPM(J,IPM)
GO TO 8060
4303 ICMPLT=3
STOP
4300 IF(X(1).EQ.XCOWLH.AND.IPP.EQ.NPTS.AND.IOVER.NE.2) GO TO 4301
IF(N.GT.NPTS) GO TO 8104
LMAX=LMAX+2
L=1
K=1
DO 510 J=1,NSP
510 ALPN(J,L)=ALPF(J,N)
XN(L)=XF(N)
YN(L)=YF(N)
QN(L)=QF(N)
PN(L)=PF(N)
TN(L)=TF(N)
THN(L)=THF(N)
WN(L)=WF(N)
RN(L)=RF(N)

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DO 1501 J=1,NSP
1501 ALPDUM(J)=ALPN(J,1)
CALL ALL (CPXN(1),WN(1),RHON(1),RN(1),GAMN(1),EMN(1),XMUN(1),QN(1)
1,TN(1),PN(1),ALPDUM)
IFENC1=1
IF (IFENCE.EQ.1.AND.XN(L).EQ.XCOWLH.AND.N.EQ.NPTS) GO TO 2601
IFENC1=0
GO TO 8060
8104 ASL=TAN(TH(1))
ACH=TAN(TH(2)+XMU(2))
XN(1)=(Y(1)-Y(2)+X(2)*ACH-X(1)*ASL)/(ACH-ASL)
DELTH=XN(1)-X(1)
IF ((DELTH/TEST).GT.1.) GO TO 9061
ICK=1
3514 YCH=Y(2)+ACH*(XN(1)-X(2))
CALL BODU(XN(1),YN(1),THN(1))
IF (I OVER.NE.2) GO TO 694
YN(1)=-YN(1)
THN(1)=-THN(1)
694 CONTINUE
DELTH=ABS(THN(1)-TH(1))
IF (DELTH.GT.02) GO TO 9061
ER=(YCH-YN(1))
IF (ABS(ER).LT.1.E-04) GO TO 3510
ICK=ICK+1
IF (ICK.LT.15) GO TO 3511
WRITE(6,3512)
3512 FORMAT(* TOO MANY ITERATIONS IN INITIAL BODU CALL FROM NOZBOD*)
STOP
3511 IF (ICK.GT.2) GO TO 3513
ER1=ER
XSL1=XN(1)
XN(1)=1.01*XN(1)
GO TO 3514
3513 DUM=XSL1-ER1*(XN(1)-XSL1)/(ER-ER1)
ER1=ER
XSL1=XN(1)
XN(1)=DUM
GO TO 3514
3510 CONTINUE
XSL=XN(1)
YSL=YN(1)
THSL=THN(1)
IF ((DELTH/TEST).LT.1.) GO TO 9060
DELTH=XN(1)-X(1)
9061 LMAX=KMAX+1
DO 9000 M1=2,KMAX
L=KMAX-M1+2
I=L+1
X(I)=X(L)
Y(I)=Y(L)
Q(I)=Q(L)
P(I)=P(L)
T(I)=T(L)
W(I)=W(L)
R(I)=R(L)
TH(I)=TH(L)
EM(I)=EM(L)
CPX(I)=CPX(L)
RHO(I)=RHO(L)

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      GAM(I)=GAM(L)
      XMU(I)=XMU(L)
      DO 9001 J=1,NSP
9001  ALP(J,I)=ALP(J,L)
9000  CONTINUE
      ISHOC=ISHOC+1
      KMAX=KMAX+1
      RAT=.5
      X(2)=X(1)+RAT*(X(3)-X(1))
      Y(2)=Y(1)+RAT*(Y(3)-Y(1))
      Q(2)=Q(1)+RAT*(Q(3)-Q(1))
      T(2)=T(1)+RAT*(T(3)-T(1))
      TH(2)=TH(1)+RAT*(TH(3)-TH(1))
      R(2)=R(1)+RAT*(R(3)-R(1))
      CALL PANDW(P(1),P(3),RAT,P(2),W(1),W(3),Q(1),Q(3),Q(2),W(2),IEQ,0)
      DO 9003 J=1,NSP
9003  ALP(J,2)=ALP(J,1)+RAT*(ALP(J,3)-ALP(J,1))
      ALPDUM(J)=ALP(J,2)
      CALL ALL(CPX(2),W(2),RHO(2),R(2),GAM(2),EM(2),XMU(2),Q(2),T(2),
1P(2),ALPDUM)
      GO TO 8104
9060  LMAX=KMAX
      A=1.
      B=0.
      IF (ISHOC.EQ.1) BETN=BET
8000  CONTINUE
      IF (B.EQ.0) THN(1)=THSL
      IT=1
8030  EMSL=XM3(.5,.5,TH(1),THN(1))
      EM1=XM1(A,B,TH(2),XMU(2),THN(1),XMUN(1))
      IF (ISHOC.EQ.1) EM1=.5*(TAN(BET)+TAN(BETN))
      XN(1)=(Y(1)-Y(2)+X(2)*EM1-X(1)*EMSL)/(EM1-EMSL)
      ICK=1
3524  YCH=Y(2)+EM1*(XN(1)-X(2))
      CALL BODU(XN(1),YN(1),THN(1))
      IF (IOVER.NE.2) GO TO 698
      YN(1)=-YN(1)
      THN(1)=-THN(1)
698  CONTINUE
      ER=(YCH-YN(1))
      IF (ABS(ER).LT.1.E-04) GO TO 3520
      ICK=ICK+1
      IF (ICK.LT.15) GO TO 3521
      WRITE(6,3522)
3522  FORMAT(* TOO MANY ITERATIONS IN FINAL BODU CALL FROM NOZBOD*)
      STOP
3521  IF (ICK.GT.2) GO TO 3523
      ER1=ER
      XSL1=XN(1)
      XN(1)=1.01*XN(1)
      GO TO 3524
3523  DUM=XSL1-ER1*(XN(1)-XSL1)/(ER-ER1)
      ER1=ER
      XSL1=XN(1)
      XN(1)=DUM
      GO TO 3524
3520  CONTINUE
8020  A1=F1(A,B,XMU(2),GAM(2),P(2),XMUN(1),GAMN(1),PN(1))
      XDUM2=X(2)-XOR(NXXJ-1)
      XDUMN=XN(1)-XOR(NXXJ-1)

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A2=F2(A,B,1.,XJ,XJ1,XDUM2,Y(2),TH(2),XMU(2),XDUMN,YN(1),THN(1),XMU
1N(1))
DUM1=A2*(XN(1)-X(2))
IF(XJ1.GT.0.) DUM1=A2*ALOG(XDUMN/XDUM2)
DUM=(TH(2)-THN(1)-DUM1)/A1
PN(1)=P(2)*EXP(DUM)
IF(B.EQ.0.) GO TO 1801
L1=1
L2=1
IF(XN(L1).GT.XCOWL-1.E-04) GO TO 1801
IF(XN(L1).GT.XXJ1(NX-XJ)-1.E-04) GO TO 1801
Z1=AXX(NXXJ-1)*(X(L2)-XBP)+BXX(NXXJ-1)
Z2=AXX(NXXJ-1)*(XN(L1)-XBP)+BXX(NXXJ-1)
DAX=(Z1+Z2)/2.*ABS(YN(L1)-Y(L2))
DAY=(Z1+Z2)/2.*(XN(L1)-X(L2))
PAV=(PN(L1)+P(L2))/2.
PAV=(PAV/PJN-1.)*PINF*144.
DXTHX=PAV*DAX
DYLEFT=-PAV*DAY
XMS=(XN(L1)+X(L2))/2.-XSHIFT
YMS=(YN(L1)+Y(L2))/2.-YSHIFT
DMOM=YMS*DXTHX-XMS*DYLEFT
XTHX=XTHX+DXTHX
YLEFT=YLEFT+DYLEFT
XMOM=XMOM+DMOM
1801 CONTINUE
DO 8050 J=1,NSP
ALPN(J,1)=ALP(J,1)
8050 ALPDUM(J)=ALPN(J,1)
IF(IEQ.EQ.1) GO TO 3000
TERM2=RHO(1)*Q(1)*A
IF(B.GT.0.) TERM2=TERM2+B*RHON(1)*QN(1)
IF(B.EQ.0.) CPXN(1)=CPX(1)
QN(1)=(P(1)-PN(1))/TERM2+Q(1)
TN(1)=T(1)+(QN(1)+Q(1))*(PN(1)-P(1))*EIN/(CPX(1)+CPXN(1))/TERM2
CALL ALL(CPXN(1),WN(1),RHON(1),RN(1),GAMN(1),EMN(1),XMUN(1),
1QN(1),TN(1),PN(1),ALPDUM)
GO TO 3001
3000 CONTINUE
RHON(1)=RHO(1)*(PN(1)/P(1))**(1./GAM(1))
VVL=Q(1)*Q(1)+2.*GAM(1)/(GAM(1)-1.)*(P(1)/RHO(1)-PN(1)/RH
1ON(1))
QN(1)=SQRT(VVL)
WN(1)=W(1)+.5*(Q(1)*Q(1)-VVL)
RN(1)=R(1)
TN(1)=FT(PN(1),RN(1),WN(1))
GAMN(1)=FGAM(TN(1),PN(1),RN(1))
EMN(1)=QN(1)/SQRT(GAMN(1)*PN(1)/RHON(1))
XMUN(1)=ATAN(1./SQRT(EMN(1)**2-1.))
3001 CONTINUE
IF(B.GT.0.) GO TO 8049
A=.5
B=.5
GO TO 8000
8049 IF(ISHOC.NE.1) GO TO 2600
CALL SHOCPT(ISHOC,3,BET,BETN,A,B)
BET=THN(2)-(BETN-THN(1))
IGG=1
2625 CALL SHOCK(BET,QN(2),THN(2),GAMN(2),EMN(2),RHON(2),PN(2),WN(2),
1RN(2),QN(1),TH2,GAMN(1),EMN(1),RHON(1),PN(1),WN(1),RN(1),TN(1),

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1XMUN(1),-1.)
ER4=THN(1)-TH2
IF (ABS(ER4).LT.1.E-04) GO TO 2601
IGG=IGG+1
IF (IGG.GT.15) GO TO 2627
IF (IGG.GT.2) GO TO 2628
ER1=ER4
BETP=BET
BET=BET+.02
GO TO 2625
2627 WRITE(6,2629)
2629 FORMAT(* ERROR IN BETA LOOP IN MAIN*)
STOP
2628 DUMM=BETP-ER1*(BET-BETP)/(ER4-ER1)
ER1=ER4
BETP=BET
BET=DUMM
GO TO 2625
2600 CONTINUE
IF (IFLIP.EQ.1.AND.XN(1).GT.XFINAL) IHALT=1
IF (XN(1).LE.XCOWL-1.E-04.AND.XN(1).LE.XXJ1(NXXJ)-1.E-04) GOTO 8060
XNN=XCOWL
IF (XN(1).GT.XXJ1(NXXJ)-1.E-04) XNN=XXJ1(NXXJ)
RAT=(XNN-X(1))/(XN(1)-X(1))
XN(1)=XNN
CALL BODU(XN(1),YN(1),THN(1))
P N(1)=P (1)+RAT*(P N(1)-P (1))
L1=1
L2=1
Z1=AXX(NXXJ-1)*(X(L2)-XBP)+BXX(NXXJ-1)
Z2=AXX(NXXJ-1)*(XN(L1)-XBP)+BXX(NXXJ-1)
DAX=(Z1+Z2)/2.*ABS(YN(L1)-Y(L2))
DAY=(Z1+Z2)/2.*(XN(L1)-X(L2))
PAV=(P N(L1)+P(L2))/2.
PAV=(PAV/P IN-1.) *P INF*144.
DXTHX=PAV*DA X
DYLF T=-PAV*DAY
XMS=(XN(L1)+X(L2))/2.-XSHFT
YMS=(YN(L1)+Y(L2))/2.-YSHFT
DMOM=YMS*DXTHX-XMS*DYLF T
XTHX=XTHX+DXTHX
YLFT=YLFT+DYLF T
XMOM=XMOM+DMOM
Q N(1)=Q (1)+RAT*(Q N(1)-Q (1))
T N(1)=T (1)+RAT*(T N(1)-T (1))
RN(1)=R(1)+RAT*(RN(1)-R(1))
WNT=WN(1)+QN(1)*QN(1)/2.
WT=W(1)+Q(1)*Q(1)/2.
WNT1=WNT+RAT*(WNT-WT)
WN(1)=W(1)+RAT*(WN(1)-W(1))
IF (IEQ.EQ.1) WN(1)=WNT1-QN(1)*QN(1)/2.
DO 3519 J=1,NSP
ALPN(J,1)=ALP(J,1)
3519 ALPDUM(J)=ALP(J,1)
CALL ALL(CPXN(1),WN(1),RHON(1),RN(1),GAMN(1),EMN(1),XMUN(1),
1QN(1),TN(1),PN(1),ALPDUM)
2601 CONTINUE
ICMPLT=1
IF (XJ1.EQ.0..AND.IOVER.EQ.0) GO TO 8060
IX=1

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IF (IFLIP.EQ.1) IX=2
2655 IAA=IAA+1
XF(IAA)=XN(IX)
YF(IAA)=YN(IX)
PF(IAA)=PN(IX)
QF(IAA)=QN(IX)
RF(IAA)=RN(IX)
WF(IAA)=WN(IX)
TF(IAA)=TN(IX)
THF(IAA)=THN(IX)
XMUF(IAA)=XMUN(IX)
GAMF(IAA)=GAMN(IX)
EM F(IAA)=EM N(IX)
RHOF(IAA)=RHON(IX)
DO 3470 J=1,NSP
3470 ALPF(J,IAA)=ALPN(J,IX)
IF (IX.EQ.1) GO TO 2656
IX=1
GO TO 2655
2656 IF (IFLIP.EQ.1) IAA=IAA-1
ICMPLT=0
NSTAR=0
IF (XN(1)+.0001.GE.XTJ1) XJ1=0.
IF (IFLIP.NE.1 ) NXXJ=NXXJ+1
IF (IFENC1.EQ.1) IFENCE=0
IF (NXXJ.GT.NXXJ1) NXXJ=NXXJ1+1
IF (XN(1).EQ.XCOWL) XCOWL=XFINAL
IF (IFLIP.GT.0) GO TO 2602
IF (ICOWL.EQ.0) GO TO 7593
RP=PMM(MM)/PF(IAA)*PIN
IF (RP.GT.1.) GO TO 5989
7593 NPTS=IAA
IOVER=0
IAA=1
GO TO 7211
5989 CONTINUE
EMEXT=EMINF*QM(MM)/SQRT(TM(MM))
CALL COWLO(IAA,THM(MM),EMEXT,BET,PMM(MM))
XINTU=XINTL
DO 691 I13=1,3
XXU(I13)=XXL(I13)
AA1(I13,1)=AA1(I13,2)
AA2(I13,1)=AA2(I13,2)
691 AA3(I13,1)=AA3(I13,2)
2602 CONTINUE
NPTS=IAA+1
IFLIP=IFLIP+1
IF (IFLIP.GT.1) XXP=XFINAL
IAA=1
LSTT=0
IOVER=2
CALL INDATA
BET=-BET
ISHOC=1
GO TO 7211
8060 CONTINUE
LM=LMAX-1
IF (XJ1.GT.0..AND..IAA.GT.1) LM=1000
IF (IOVER.EQ.2..AND..LSTT.EQ.1) LM=1000
LST=0

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L=1
M=0
IDPT=0
XFP=XFINAL
IF (NSTAR.EQ.1) M=2
IF (ICMPLT.EQ.2) M=1
5520 L=L+1
IF (L.GT.LM) GO TO 6520
K=L-1
678 M=M+1
A=1.
B=0.
250 CONTINUE
IF (L.EQ.ISHOC+1) CALL SHOCPT(ISHOC,M,BET,BETN,A,B)
IF (L.NE.ISHOC+1.OR.B.EQ.0..OR.IFLIP.NE.1) GO TO 2603
IPL=3
2684 POLYC=-AA3(IPL,1)-YN(L)+TAN(BETN)*(XN(L)-XINTU)
POLYB=-AA2(IPL,1)-TAN(BETN)
POLYA=-AA1(IPL,1)
IF (POLYA.NE.0.)
1XPP=(-POLYB-SQRT(POLYB*POLYB-4.*POLYA*POLYC))/(2.*POLYA)
IF (POLYA.EQ.0.) XPP=-POLYC/POLYB
XPP=XPP+XINTU
IF (XPP.GE.XXU(IPL)) GO TO 2603
IPL=IPL-1
GO TO 2684
2603 CONTINUE
IF (L.EQ.ISHOC+1) GO TO 3003
EM1=XM1(A,B,THN(M),XMU(M),THN(L),XMUN(L))
EM9=EM1
IF (L.EQ.ISHOC) EM1=TAN(BET)
IF (L.EQ.ISHOC.AND.M.GT.1) EM1=TAN(BET+THN(L-1)+XMUN(L-1)-THN(M-1)
1-XMU(M-1))
EM2=XM2(A,B,THN(K),XMUN(K),THN(L),XMUN(L))
XN(L)=(YN(K)-Y(M)+EM1*X(M)-EM2*XN(K))/(EM1-EM2)
YN(L)=Y(M)+EM1*(XN(L)-X(M))
IF (B.GT.0.) GO TO 681
IDROP=0
BETT=BET
IF (M.GT.1.AND.IOVER.EQ.2) BETT=BET+THN(L-1)+XMUN(L-1)-THN(M-1)-XMU(M
1-1)
IF (L.EQ.ISHOC-1) CALL DRTEST(XN(L),YN(L),EM1,BETT,IDROP,+1,M)
IF (L.EQ.ISHOC+2) CALL DRTEST(XN(L),YN(L),EM1,BETN,IDROP,-1,M)
IF (IDROP.EQ.0) GO TO 681
LMAX=LMAX-1
LM=LM-1
IF (L.LT.ISHOC) ISHOC=ISHOC-1
GO TO 678
681 CONTINUE
IF (L.NE.ISHOC) GO TO 601
YSHOC=Y(M)
XSHOC=X(M)
IF (L.GT.2) GO TO 602
YDUM=YN(L)-EM9*(XN(L)-X(M))
XDUM=X(M)
RAT=(YDUM-Y(M))/(YN(1)-Y(M))
Y(M)=YDUM
X(M)=XDUM
QHD=Q(M)
Q(M)=Q(M)+RAT*(Q(N(1))-Q(M))

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T (M)=T (M)+RAT*(T N( 1)-T (M))
R (M)=R (M)+RAT*(R N( 1)-R (M))
CALL PANDW(P (M),PN(1),RAT,P (M),W (M),WN(1),GH0,QN(1),Q (M),W (M),IEQ
1,0)
TH (M)=TH (M)+RAT*(TH N( 1)-TH (M))
XMU(M)=XMU(M)+RAT*(XMUN( 1)-XMU(M))
GAM(M)=GAM(M)+RAT*(GAMN( 1)-GAM(M))
DO 644 J=1,NSP
644 ALP(J,M)=ALP(J,M)+RAT*(ALPN(J, 1)-ALP(J,M))
GO TO 601
602 CONTINUE
EM8=XM2(.5,.5,TH(M-1),XMU(M-1),TH(M),XMU(M))
YDUM=(EM9*Y(M)-EM8*YN(L)+EM8*EM9*(XN(L)-X(M)))/(EM9-EM8)
XDUM=XN(L)-(YN(L)-YDUM)/EM9
RAT=(YDUM-Y(M))/(Y(M-1)-Y(M))
Y(M)=YDUM
X(M)=XDUM
GH0=Q(M)
Q (M)=Q (M)+RAT*(Q (M-1)-Q (M))
T (M)=T (M)+RAT*(T (M-1)-T (M))
R (M)=R (M)+RAT*(R (M-1)-R (M))
CALL PANDW(P(M),P(M-1),RAT,P(M),W(M),W(M-1),GH0,Q(M-1),Q(M),W(M)
1,IEQ,0)
TH (M)=TH (M)+RAT*(TH (M-1)-TH (M))
XMU(M)=XMU(M)+RAT*(XMU(M-1)-XMU(M))
GAM(M)=GAM(M)+RAT*(GAM(M-1)-GAM(M))
DO 604 J=1,NSP
604 ALP(J,M)=ALP(J,M)+RAT*(ALP(J,M-1)-ALP(J,M))
601 CONTINUE
A1=F1(A,B,XMU(M),GAM(M),P(M),XMUN(L),GAMN(L),PN(L))
B1=F1(A,B,XMUN(K),GAMN(K),PN(K),XMUN(L),GAMN(L),PN(L))
XDUMK=XN(K)-XOR(NXXJ-1)
XDUMM=X(M)-XOR(NXXJ-1)
XDUML=XN(L)-XOR(NXXJ-1)
A2=F2(A,B,1.,XJ,XJ1,XDUMM,Y(M),TH(M),XMU(M),XDUML,YN(L),THN(L),XMU
1N(L))
B2=F2(A,B,-1.,XJ,XJ1,XDUMK,YN(K),THN(K),XMUN(K),XDUML,YN(L),THN(L)
1,XMUN(L))
DUM1=-(A2+B2)*XN(L)+A2*X(M)+B2*XN(K)
IF(XJ1.GT.0.)DUM1=-(A2*ALOG(XDUML/XDUMM)+B2*ALOG(XDUML/XDUMK))
DUM=(A1*ALOG(P(M))+B1*ALOG(PN(K))+TH(M)-THN(K)+DUM1)/(A1+B1)
PN(L)=EXP(DUM)
DUM=ALOG(P(M)/PN(L))*A1
DUM2=XN(L)-X(M)
IF(XJ1.NE.0.) DUM2=ALOG(XDUML/XDUMM)
THN(L)=DUM+TH(M)-A2*DUM2
253 EM3A=XM3(.5,.5,TH(M),THN(L))
EM3B=XM3(.5,.5,THN(K),THN(L))
EM3=.5*(EM3A+EM3B)
TESTX=ABS(XN(K)-X(M))
TESTY=ABS(YN(K)-Y(M))
IF(TESTX.GE.1.E-10)
1SLOPE=(YN(K)-Y(M))/(XN(K)-X(M))
IF(TESTX.LT.1.E-10) SLOPE=1.E10
XD=(YN(L)-Y(M)+SLOPE*X(M)-EM3*XN(L))/(SLOPE-EM3)
IF(NSTAR.EQ.0) GO TO 6881
XX=ABS(1.-X(M)/XN(K))
IF(XX.LT..001) XD=(XN(K)+X(M))/2.
6881 YD=YN(L)+EM3*(XD-XN(L))
IF(TESTX.LE.TESTY) GO TO 2250

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      KIP=0
2230  RATD=(XD-X(M))/(XN(K)-X(M))
      THD=TH(M)+RATD*(THN(K)-TH(M))
      EM3=XM3(.5,.5,THD,THN(L))
      XDT=XD
      XD=(YN(L)-Y(M)+SLOPE*X(M)-EM3*XN(L))/(SLOPE-EM3)
      YD=YN(L)+EM3*(XD-XN(L))
      IF(ABS((XDT-XD)/TESTX).LT..001) GO TO 2231
      KIP=KIP+1
      IF(KIP.GT.20) CALL ERROR(2230)
      GO TO 2230
2231  RATD=(XD-X(M))/(XN(K)-X(M))
      GO TO 2235
2250  CONTINUE
      KIP=0
230  RATD=(YD-Y(M))/(YN(K)-Y(M))
      THD=TH(M)+RATD*(THN(K)-TH(M))
      EM3=XM3(.5,.5,THD,THN(L))
      YDT=YD
      XD=(YN(L)-Y(M)+SLOPE*X(M)-EM3*XN(L))/(SLOPE-EM3)
      YD=YN(L)+EM3*(XD-XN(L))
      IF(ABS((YDT-YD)/(YN(K)-Y(M))).LT..001) GO TO 231
      KIP=KIP+1
      IF(KIP.GT.20) CALL ERROR(230)
      GO TO 230
231  RATD=(YD-Y(M))/(YN(K)-Y(M))
2235  CONTINUE
      QD=Q(M)+RATD*(QN(K)-Q(M))
      TD=T(M)+RATD*(TN(K)-T(M))
      THD=TH(M)+RATD*(THN(K)-TH(M))
      PD=P(M)+RATD*(PN(K)-P(M))
      RD=R(M)+RATD*(RN(K)-R(M))
      WMT=W(M)+Q(M)*Q(M)/2.
      WK T=WN(K)+QN(K)*QN(K)/2.
      WD T=WMT+RATD*(WK T-WMT)
      WD=W(M)+RATD*(WN(K)-W(M))
      IF(IEQ.EQ.1) WD=WD T-QD*QD/2.
      DO 235 J=1,NSP
235  ALPD(J)=ALP(J,M)+RATD*(ALPN(J,K)-ALP(J,M))
      CALL ALL(CPXD,WD,RHOD,RD,GAMD,EMD,XMUD,QD,TD,PD,ALPD)
      DO 1502 J=1,NSP
      ALPN(J,L)=ALPD(J)
1502  ALPDUM(J)=ALPN(J,L)
      IF(IEQ.EQ.1) GO TO 3002
      TERM2=RHOD*QD
      IF(B.GT.0.) TERM2=(TERM2+RHON(L)*QN(L))/2.
      IF(B.EQ.0.) CPXN(L)=CPXD
      QN(L)=(PD-PN(L))/TERM2+QD
      TN(L)=TD+(QN(L)+QD)*(PN(L)-PD)*EIN/(CPXD+CPXN(L))/TERM2
      CALL ALL(CPXN(L),WN(L),RHON(L),RN(L),GAMN(L),EMN(L),XMUN(L),QN(L)
1,TN(L),PN(L),ALPDUM)
      GO TO 3003
3002  CONTINUE
      RHON(L)=RHOD*(PN(L)/PD)**(1./GAMD)
      VVL=QD*QD+2.*GAMD/(GAMD-1.)*(PD/RHOD-PN(L)/RH
1ON(L))
      QN(L)=SQRT(VVL)
      WN(L)=WD+.5*(QD*QD-VVL)
      RN(L)=RD
      TN(L)=FT(PN(L),RN(L),WN(L))

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      GAMN(L)=FGAM(TN(L),PN(L),RN(L))
      EMN(L)=QN(L)/SQRT(GAMN(L)*PN(L)/RHON(L))
      XMUN(L)=ATAN(1./SQRT(EMN(L)**2-1.))
3003 CONTINUE
      IF(IDPT.EQ.0) GO TO 8400
      IF(B.GT.0.) GO TO 8401
      A=.5
      B=.5
      GO TO 253
8400 CONTINUE
      IF(B.GT.0.) GO TO 7520
      IF(L.NE.ISHOC) GO TO 606
      IF(L.GT.2) GO TO 650
      RAT=(YN(1)-YSHOC)/(YN(1)-Y(M))
      Y(M)=YSHOC
      X(M)=XSHOC
      QH0=Q(M)
      Q(M)=Q(M)+RAT*(Q(N(1))-Q(M))
      T(M)=T(M)+RAT*(T(N(1))-T(M))
      R(M)=R(M)+RAT*(R(N(1))-R(M))
      CALL PANDW(P(M),PN(1),RAT,P(M),W(M),WN(1),QH0,QN(1),Q(M),W(M),IE0
1,0)
      TH(M)=TH(M)+RAT*(TH(N(1))-TH(M))
      XMU(M)=XMU(M)+RAT*(XMUN(1)-XMU(M))
      GAM(M)=GAM(M)+RAT*(GAMN(1)-GAM(M))
      DO 655 J=1,NSP
655 ALP(J,M)=ALP(J,M)+RAT*(ALPN(J,1)-ALP(J,M))
      GO TO 606
650 CONTINUE
      RAT=(Y(M-1)-YSHOC)/(Y(M-1)-Y(M))
      Y(M)=YSHOC
      X(M)=XSHOC
      QH0=Q(M)
      Q(M)=Q(M)+RAT*(Q(M-1)-Q(M))
      T(M)=T(M)+RAT*(T(M-1)-T(M))
      R(M)=R(M)+RAT*(R(M-1)-R(M))
      CALL PANDW(P(M),P(M-1),RAT,P(M),W(M),W(M-1),QH0,Q(M-1),Q(M),W(M)
1,IEQ,0)
      TH(M)=TH(M)+RAT*(TH(M-1)-TH(M))
      XMU(M)=XMU(M)+RAT*(XMU(M-1)-XMU(M))
      GAM(M)=GAM(M)+RAT*(GAM(M-1)-GAM(M))
      DO 605 J=1,NSP
605 ALP(J,M)=ALP(J,M)+RAT*(ALP(J,M-1)-ALP(J,M))
606 CONTINUE
      A=.5
      B=.5
      GO TO 250
7520 CONTINUE
      IF(IFENCE.EQ.0.OR.XN(1).NE.XCOWLH) GO TO 3108
      XXP=(YN(L)-BFENCE)/AFENCE+XBP
      IF(XN(L).LT.XXP) GO TO 520
      DUM=(YN(L)-YN(K))/(XN(L)-XN(K))
      XXP=(AFENCE*XBP-BFENCE-DUM*XN(K)+YN(K))/(AFENCE-DUM)
3108 CONTINUE
      IF(XJ1.EQ.0..AND.IOVER.EQ.0) GO TO 520
      IF(XN(L).LT.XXJ1(NXXJ).AND.XN(L).LT.XXP) GO TO 520
      IF(LST.GT.0) GO TO 520
      LST=1
      XNN=XXP
      IF(XN(L).GE.XXJ1(NXXJ)) XNN=XXJ1(NXXJ)

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      RAT=(XNN-XN(K))/(XN(L)-XN(K))
      IAA=IAA+1
      IF(IPP.GT.NPTS.OR.IAA.LT.IPP)GO TO 3999
      WRITE(6,3998)
3998  FORMAT(* INDEXING IN CHANGE OF ORIGIN OVERLAPS INITIAL DATA IAA EQ
1UALS IPP*)
      STOP
3999  XN(L)=XNN
      YN(L)=YN(K)+RAT*(YN(L)-YN(K))
      THN(L)=THN(K)+RAT*(THN(L)-THN(K))
      DUM1=ALOG(PN(K))
      DUM2=ALOG(PN(L))
      DUM=DUM1+RAT*(DUM2-DUM1)
      PN(L)=EXP(DUM)
      IDPT=1
      A=1.
      B=0.
      GO TO 253
8401  IDPT=0
      IF(IFENCE.EQ.0.OR.XN(1).NE.XCOWLH) GO TO 9804
      IF(IAA.LT.3.OR.XF(1).EQ.XFENCE) GO TO 9804
      WRITE(6,9805)
9805  FORMAT(* FENCE MAY NOT BE ENTIRELY SUPERSONIC - CHECK FLOW FIELD*)
      STOP
9804  CONTINUE
      XF(IAA)=XN(L)
      YF(IAA)=YN(L)
      QF(IAA)=QN(L)
      RF(IAA)=RN(L)
      WF(IAA)=WN(L)
      TF(IAA)=TN(L)
      PF(IAA)=PN(L)
      THF(IAA)=THN(L)
      DO 8402 J=1,NSP
8402  ALPF(J,IAA)=ALPN(J,L)
      IF(IAA.EQ.2.AND.LSTT.EQ.0) GO TO 520
      LMAX=L
      GO TO 265
520  CONTINUE
      IF(XN(L).LT.XXJ1(NXXJ).AND.XN(L).LT.XXP) GO TO 5520
      IF(LSTT.EQ.0) GO TO 5520
      LMAX=L
      GO TO 265
6520  CONTINUE
      A=1.
      B=0.
      L=LMAX
      KK=KMAX
      K=LMAX-1
5011  CONTINUE
      IF(B.EQ.0.) THN(L)=TH(KK)
      IB=1
630  CONTINUE
      EMSL=XM3(.5,.5,TH(KK),THN(L))
      EM2=XM2(A,B,THN(K),XMUN(K),THN(L),XMUN(L))
      IF(IDESGN.EQ.0.AND.IFLIP.NE.1)
1CALL BODL(X(KK),Y(KK),TH(KK),XN(K),YN(K),EM2,XN(L),YN(L),THN(L))
      IF(IFLIP.NE.1) GO TO 631
      XN(L)=(YN(K)-Y(KK)+EMSL*X(KK)-EM2*XN(K))/(EMSL-EM2)
      YN(L)=Y(KK)+EMSL*(XN(L)-X(KK))

```


631 CONTINUE

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B1=F1(A,B,XMUN(K),GAMN(K),PN(K),XMUN(L),GAMN(L),PN(L))
XDUMK=XN(K)-XOR(NXXJ-1)
XDUML=XN(L)-XOR(NXXJ-1)
B2=F2(A,B,-1.,XJ,XJ1,XDUMK,YN(K),THN(K),XMUN(K),XDUML,YN(L),THN(L)
1,XMUN(L))
DUM1=B2*(XN(L)-XN(K))
IF(XJ1.GT.0.)DUM1=B2*ALOG(XDUML/XDUMK)
DUM=(THN(L)-THN(K)-DUM1)/B1
PN(L)=PN(K)*EXP(DUM)
IF(B.EQ.0.) GO TO 1821
L1=LMAX
L2=KMAX
IF(XN(L1).GT.XXJ1(NXXJ)-1.E-04) GO TO 1821
Z1=AXX(NXXJ-1)*(X(L2)-XBP)+BXX(NXXJ-1)
Z2=AXX(NXXJ-1)*(XN(L1)-XBP)+BXX(NXXJ-1)
DAX=(Z1+Z2)/2.*ABS(YN(L1)-Y(L2))
DAY=(Z1+Z2)/2.*(XN(L1)-X(L2))
PAV=(PN(L1)+P(L2))/2.
PAV=(PAV/PIN-1.)*PINF*144.
DXTHX=PAV*DAV
DYLFT=PAV*DAY
XMS=(XN(L1)+X(L2))/2.-XSHFT
YMS=(YN(L1)+Y(L2))/2.-YSHFT
DMOM=YMS*DXTHX-XMS*DYLFT
XTHX=XTHX+DXTHX
YLFT=YLFT+DYLFT
XMOM=XMOM+DMOM

```

1821 CONTINUE

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DO 1503 J=1,NSP
ALPN(J,L)=ALP(J,KK)
1503 ALPDUM(J)=ALPN(J,L)
IF(IEQ.EQ.1) GO TO 3004
TERM2=RHOK(KK)*Q(KK)*A
IF(B.GT.0.) TERM2=TERM2+B*RHON(L)*QN(L)
QN(L)=(P(KK)-PN(L))/TERM2+Q(KK)
IF(B.EQ.0.) CPXN(L)=CPX(KK)
TN(L)=T(KK)+(QN(L)+Q(KK))*((PN(L)-P(KK))*EIN/(CPX(KK)+CPXN(L)))/T
1ERM2
CALL ALL(CPXN(L),WN(L),RHON(L),RN(L),GAMN(L),EMN(L),XMUN(L),QN(L)
1,TN(L),PN(L),ALPDUM)
GO TO 3005

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3004 CONTINUE

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RHON(L)=RHOK(KK)*(PN(L)/P(KK))*((1./GAM(KK))
VVL=Q(KK)*Q(KK)+2.*GAM(KK)/(GAM(KK)-1.)*(P(KK)/RHOK(KK)-PN(L)/RH
1ON(L))
QN(L)=SQRT(VVL)
WN(L)=W(KK)+.5*(Q(KK)*Q(KK)-VVL)
RN(L)=R(KK)
TN(L)=FT(PN(L),RN(L),WN(L))
GAMN(L)=FGAM(TN(L),PN(L),RN(L))
EMN(L)=QN(L)/SQRT(GAMN(L)*PN(L)/RHON(L))
XMUN(L)=ATAN(1./SQRT(EMN(L)**2-1.))

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3005 CONTINUE

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IF(IFLIP.NE.1) GO TO 632
P2=PN(L)/P(KK)
CALL PM(P2,TH(KK),EMC1,TH2T,EMC2,+1)
ER4=TH2T-THN(L)
IF(ABS(ER4).LT.1.E-04) GO TO 632
IB=IB+1

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IF (IB.GT.15) GO TO 633
IF (IB.GT.2) GO TO 634
ER6=ER4
THSVV=THN(L)
THN(L)=THN(L)-.01*ABS(THN(L))
GO TO 630
633 WRITE(6,635)
635 FORMAT(* ERROR IN PM LOOP AT CONTACT IN MAIN*)
STOP
634 DUM1=THSVV-ER6*(THN(L)-THSVV)/(ER4-ER6)
ER6=ER4
THSVV=THN(L)
THN(L)=DUM1
GO TO 630
632 CONTINUE
IF (B.GT.0.) GO TO 1265
A=.5
B=.5
GO TO 5011
1265 IAAS=IAA
IF (IFLIP.EQ.2.AND.XN(L).GE.XFINAL) IHALT=1
IF (IHALT.EQ.1) GO TO 1802
IF (XN(L).GE.XFINAL) GO TO 1802
IF (XJ1.EQ.0.AND.IOVER.EQ.0) GO TO 265
IF (IFENCE.EQ.0.OR.XN(1).NE.XCOWLH) GO TO 3109
IF (XN(L).LT.XFENCE) GO TO 265
XNN=XFENCE
GO TO 3110
3109 CONTINUE
IF (XN(L).LT.XXJ1(NXXJ)) GO TO 265
1802 CONTINUE
XNN=XXJ1(NXXJ)
3110 CONTINUE
RAT=(XNN-X(KK))/(XN(L)-X(KK))
IAA=1
LSTT=1
XF(IAA)=XNN
IF (IFLIP.EQ.1) GO TO 2605
XCH=XNN-XINTL
LK=3
IF (XCH.LT.XXL(3)) LK=2
IF (XCH.LT.XXL(2)) LK=1
YF(IAA)=AA1(LK,2)*XCH*XCH+AA2(LK,2)*XCH+AA3(LK,2)
THF(IAA)=ATAN(2.*AA1(LK,2)*XCH+AA2(LK,2))
GO TO 2606
2605 YF(IAA)=Y(KK)+RAT*(YN(L)-Y(KK))
THF(IAA)=ATAN(TAN(TH(KK))+RAT*(TAN(THN(L))-TAN(TH(KK))))
2606 CONTINUE
QF(IAA)=Q(KK)+RAT*(QN(L)-Q(KK))
RF(IAA)=R(KK)+RAT*(RN(L)-R(KK))
PF(IAA)=P(KK)+RAT*(PN(L)-P(KK))
L1=IAA
L2=KMAX
Z1=AXX(NXXJ-1)*(X(L2)-XBP)+BXX(NXXJ-1)
Z2=AXX(NXXJ-1)*(XF(L1)-XBP)+BXX(NXXJ-1)
DAX=(Z1+Z2)/2.*ABS(YF(L1)-Y(L2))
DAY=(Z1+Z2)/2.*(XF(L1)-X(L2))
PAV=(PF(L1)+P(L2))/2.
PAV=(PAV/PIN-1.)*PINF*144.
DXTHX=PAV*DAX

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DYLFT=+PAV*DAY
XMS=(XN(L1)+X(L2))/2. -XSHFT
YMS=(YF(L1)+Y(L2))/2.-YSHFT
DMOM=YMS*DXTHX-XMS*DYLFT
XTHX=XTHX+DXTHX
YLFT=YLFT+DYLFT
XMOM=XMOM+DMOM
WF(IAA)=W(KK)+RAT*(WN(L)-W(KK))
TF(IAA)=T(KK)+RAT*(TN(L)-T(KK))
WA=W(KK)+Q(KK)*Q(KK)/2.
IF(IEQ.EQ.1) WF(IAA)=WA-QF(IAA)*QF(IAA)/2.
DO 3841 J=1,NSP
3841 ALP(J,IAA)=ALP(J,KK)+RAT*(ALPN(J,L)-ALP(J,KK))
IAA=IAAS
265 CONTINUE
C IF(PN(LMAX),LE,PEN,AND,IDESEN,EQ.1) GO TO 7634
KMAX=LMAX
BE T=BE TN
EMC1=EMC2
DO 270 K=1,KMAX
X(K)=XN(K)
Y(K)=YN(K)
Q(K)=QN(K)
T(K)=TN(K)
TH(K)=THN(K)
P(K)=PN(K)
R(K)=R N(K)
W(K)=W N(K)
CPX(K)=CPXN(K)
RHO(K)=RHON(K)
GAM(K)=GAMN(K)
EM(K)=EM N(K)
XMU(K)=XMUN(K)
DO 271 J=1,NSP
271 ALP(J,K)=ALPN(J,K)
DO 1504 J=1,NSP
1504 ALPDUM(J)=ALP(J,K)
CALL ALL (CPX(K),W(K),RHO(K),R(K),GAM(K),EM(K),XMU(K),Q(K),T(K),
1P(K),ALPDUM)
270 CONTINUE
7266 IF(N-NPTS) 7201,7202,500
7201 N=N+1
GO TO 500
7202 CONTINUE
NSTAR=1
IPPSV=IPP+1
N=N+1
GO TO 500
9123 KTEST=KMAX/2
KTEST1=(KMAX-1)/2
KT3=KMAX-1
IF(KTEST.EQ.KTEST1) KT3=KMAX
I=0
DO 6412 L=1,KT3,2
I=I+1
X(I)=X(L)
Y(I)=Y(L)
Q(I)=Q(L)
P(I)=P(L)
T(I)=T(L)

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```

W (I)=W (L)
R (I)=R (L)
TH (I)=TH (L)
EM (I)=EM (L)
CPX(I)=CPX(L)
RHO(I)=RHO(L)
GAM(I)=GAM(L)
XMU(I)=XMU(L)
DO 6414 J=1,NSP
6414 ALP(J,I)=ALP(J,L)
6412 CONTINUE
IF(KTEST.EQ.KTEST1) GO TO 6413
I=I+1
L=KMAX
X (I)=X (L)
Y (I)=Y (L)
Q (I)=Q (L)
P (I)=P (L)
T (I)=T (L)
W (I)=W (L)
R (I)=R (L)
TH (I)=TH (L)
EM (I)=EM (L)
CPX(I)=CPX(L)
RHO(I)=RHO(L)
GAM(I)=GAM(L)
XMU(I)=XMU(L)
DO 6415 J=1,NSP
6415 ALP(J,I)=ALP(J,L)
6413 KMAX=KMAX/2+1
LMAX=KMAX
GO TO 6060
END

```

```

SUBROUTINE INDATA
COMMON/COWL/ICOWL,MM,XM(9),YM(9),PM(9),WM(9),RHM(9),THM(9),QM(9),
1RM(9),TM(9),GM(9),XMUM(9),EMM(9),ALPM(7,9),CPXM(9)
COMMON/SHAPE/ A1(3,2),A2(3,2),A3(3,2),XXU(3),XXL(3),XINTU,XINTL
COMMON/LTM/XSHFT,YSHFT,XTHX,YLFT,XMOM
COMMON/XXJ/NXXJ1,XXJ1(6),AXX(6),BXX(6),XOR(6)
COMMON/XFINAL/XFINAL
COMMON /SP/ NSP
COMMON/A/ TIN,CPIN,R0
COMMON/B/ WTMOLE
COMMON/D/ GAMINF,EMINF,RINF,WINF
COMMON/F/A9,B9,IBOD,XWF,NBOD,YEND
COMMON/ETX/XJ,XJ1,NPTS,I0,IREFL,ICHEM,IPUNCH,IDESGN,IR,NXX,XBP,
1YBP,THBP,RAD,XBOD,YBOD,THBOD,RADB,XEND,THEND,RTH,YEXIT,THST,TEST,
1IRFL,Y0,RADB2,RRAD(20), NSTAR,YN0Z,EIN, PEN,R16,H17
COMMON/XF/XF(200),YF(200),PF(200),QF(200),TF(200),THF(200),ALPF(
110,200)
COMMON/X/ X(200),Y(200),P(200),Q(200),T(200),TH(200),ALP(10,200)
COMMON/XCOWL/XCOWL
COMMON/FVAR/
1RHOF(200),CPXF(200),EMF(200),XMUF(200),WF(200),RF(200),GAMF(200),
2XMASSF(200), HF(200),SF(200),ALPD(10),
3THETA(20)
COMMON/VAR/RHO(200),
1EM(200),XMU(200),CPX(200),W(200),R(200),GAM(200),XMASS(200),
2 XN(200),YN(200),QN(200),TN(200),PN(200),THN(200),RHON
3(200),EMN(200),XMUN(200),CPXN(200),WN(200),RN(200),GAMN(200),
4XMASSN(200),ALPN(10,200),SI(10),HI(10), ERR(20),TEMP(20)
5,ALPDUM(10)
COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
COMMON /IOVER/ IOVER
COMMON/XTJ1/XTJ1
COMMON/FEENCE/IFENCE,BFENCE,XFENCE
DIMENSION WTMOLE(10),TYPE(6),TYPE1(4),TYPE2(2),TYPE5(4),TYPE4(4)
DATA TYPE2/10HNOZZLE,10HCENTERBODY/
DATA TYPE1/10HHYDROGENA,10HHYDROCARBO,2HIR,5HN AIR/
DATA TYPE/10HTWODIMENS,10HAXISYMMETR,10HLINESOURCE,5HIONAL,5HIC
1,5HE /
DATA TYPE5/10HFLOW,10HDES,9HFIELD,9HIGN /
DATA TYPE4/10HFROZEN,10HEQUILIBRIU,1H,1HM/
DATA XXU/3*1.E+06/,XXL/3*1.E+06/,END/1.E+06/
DATA IOVER/0/
400 FORMAT(1H1)
16 FORMAT(3X,14,3X,10E12,4)
1602 FORMAT(10X,10E12,4)
IF(IOVER.EQ.2) GO TO 916
IO=0
IREFL=0
IPUNCH=0
IDESGN=0
ICHEM=0
READ(5,6895) J1,J2,NPTS,IEQ,ICOWL,IOVER
5100 NSP=7
6895 FORMAT(16I5)
READ(5,63) XBP,XBOD,XCOWL,RTH,TEST,XFINAL,XTJ1
READ(5,63) XSHFT,YSHFT,XTHX,YLFT,XMOM
READ(5,6895) NXXJ1
DO 9393 I=1,NXXJ1
9393 READ(5,9463) XXJ1(I),AXX(I),BXX(I),XOR(I)

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```

9463 FORMAT(4E10.0)
      READ(5,4) IFENCE,AFENCE,BFENCE,XFENCE
4     FORMAT(15,5X3E10.0)
      XXJ1(NXXJ1+1)=XFINAL
      AXX(NXXJ1+1)=AXX(NXXJ1)
      BXX(NXXJ1+1)=BXX(NXXJ1)
      XOR(NXXJ1+1)=XOR(NXXJ1)
      IF(IFENCE.EQ.0) GO TO 321
      XXJ1(NXXJ1+2)=XFINAL
      AXX(NXXJ1+2)=AXX(NXXJ1)
      BXX(NXXJ1+2)=BXX(NXXJ1)
      XOR(NXXJ1+2)=XOR(NXXJ1)
321   CONTINUE
      XINTU=XB P
      XINTL=XB CD
      READ(5,6895) NUWSEG,NLWSEG
      READ(5,6363) (XXU(L),A1(L,1),A2(L,1),A3(L,1),L=1,NUWSEG)
      READ(5,6363) (XXL(L),A1(L,2),A2(L,2),A3(L,2),L=1,NLWSEG)
6363  FORMAT(4E10.0)
3531  WRITE(6,7329) TYPE5(IDESGN+1),TYPE5(IDESGN+3)
7329  FORMAT(      41X*N O Z Z L E      -      C E N T E R B O D Y *//50XA10,A9)
      JP1=J1+1+2*J2
      JP2=JP1+3
      WRITE(6,7330) TYPE(JP1),TYPE(JP2),TYPE1(ICHEM+1)
1,TYPE1(ICHEM+3),NPTS,RTH
7330  FORMAT(      /37X,*F O R      N O N U N I F O R M      G A S      F L O W
2*///
      10X,*TYPE OF FLOW IS *,A10,A5,* FOR *,
3A10,A5/10X,*NUMBER OF POINTS ON INITIAL DATA LINE IS *,I3/10X,
4*THROAT RADIUS (RTH) = *,E13.5)
      WRITE(6,5001) TYPE4(IEQ+1),TYPE4(IEQ+3)
5001  FORMAT(
110X*CHEMISTRY IS *A10,A1)
      WRITE(6,7500) XCOWL,XFINAL
7500  FORMAT(10X*COWL TRAILING EDGE IS *E13.5/10X*AXIAL COORDINATE OF EN
1D OF RUN IS *E13.5)
      IF(J2.EQ.0) GO TO 7510
      WRITE(6,7501) XTJ1
7501  FORMAT(10X*AXIAL COORDINATE OF START OF CARTESIAN SYSTEM IS *E13.5
1)
      WRITE(6,7502)
7502  FORMAT(/25X*LINE SOURCE COORDINATES*)
      WRITE(6,7505)
      DO 7503 I=1,NXXJ1
7503  WRITE(6,7504) XXJ1(I),XXJ1(I+1),AXX(I),BXX(I),XOR(I)
7504  FORMAT(10X,4E11.3,5X,E11.3)
7505  FORMAT(15X*X*4X*TO*4X*X*11X*COORDINATES*12X*ORIGIN X*)
7510  CONTINUE
      WRITE(6,2020)
2020  FORMAT(/25X*UPPER WALL COORDINATES*)
      WRITE(6,2071)
2071  FORMAT(15X*X*4X*TO*4X*X*15X*COORDINATES*)
2042  FORMAT(10X,5E11.3)
      DO 2050 I=1,NUWSEG
      IF(I.EQ.3) GO TO 2051
      WRITE(6,2042) XXU(I),XXU(I+1),A1(I,1),A2(I,1),A3(I,1)
      GO TO 2050
2051  WRITE(6,2042) XXU(I),END ,A1(I,1),A2(I,1),A3(I,1)
2050  CONTINUE
      WRITE(6,2010)
2010  FORMAT(/25X*LOWER WALL COORDINATES*)

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WRITE(6,2071)
DO 2040 I=1,NLWSEG
IF(I.EQ.3) GO TO 2041
WRITE(6,2042) XXL(I),XXL(I+1),A1(I,2),A2(I,2),A3(I,2)
GO TO 2040
2041 WRITE(6,2042) XXL(I),END ,A1(I,2),A2(I,2),A3(I,2)
2040 CONTINUE
DO 7373 L=1,NLWSEG
7373 XXU(L)=XXU(L)-XINTU
DO 7374 L=1,NLWSEG
7374 XXL(L)=XXL(L)-XINTL
3532 CONTINUE
READ(5,63) EMINF,TIN,WINF,PINF
DO 5002 I=1,NPTS
DO 5002 J=1,NSP
5002 ALPF(J,I)=0.
READ(5,6364) (XF(I),YF(I),PF(I),QF(I),TF(I),THF(I),RF(I),I=1,NPTS)
IF(IEQ.EQ.0)
1 READ(5,6364) ((ALPF(J,I),J=1,NSP),I=1,NPTS)
6364 FORMAT(7E10.0)
IF(ICOWL.EQ.1) READ(5,8698) MM, PM(MM),QM(MM),TM(MM),
1 THM(MM),RM(MM)
IF(IEQ.NE.0.OR.ICOWL.NE.1) GO TO 7511
WRITE(6,7512)
7512 FORMAT(* FROZEN EXTERNAL CASE NOT ALLOWED*/ * CHECK INPUT MANUAL FO
1R POSSIBLE USES OF IEQ AND ICOWL*)
STOP
7511 CONTINUE
8698 FORMAT(I5,5X,5E10.0)
IF(ICOWL.EQ.1) WRITE(6,5005) MM,PM(MM),QM(MM),TM(MM),THM(MM),RM(MM)
5005 FORMAT(/20X*DATA AT COWL*/10X*NUMBER OF POINTS IN PRANDTL-MEYER F
1AN IS *I2/10X*PRESSURE =*E13.5/10X*VELOCITY =*E
113.5/10X*TEMPERATURE =*E13.5/10X*FLOW INCLINATION =*E13.5/
110X*FUEL TO AIR RATIO =*E13.5)
IF(IREFL.EQ.0) GO TO 4000
916 CONTINUE
DO 4005 I=1,NPTS
II=NPTS-I+1
X(II)=XF(I)
Y(II)=-YF(I)
Q(II)=QF(I)
T(II)=TF(I)
P(II)=PF(I)
TH(II)=-THF(I)
R(II)=RF(I)
W(II)=WF(I)
DO 4010 J=1,NSP
4010 ALP(J,II)=ALPF(J,I)
4005 CONTINUE
DO 4006 I=1,NPTS
XF(I)=X(I)
YF(I)=Y(I)
QF(I)=Q(I)
TF(I)=T(I)
PF(I)=P(I)
THF(I)=TH(I)
RF(I)=R(I)
WF(I)=W(I)
DO 4007 J=1,NSP
4007 ALPF(J,I)=ALP(J,II)

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```

4006 CONTINUE
DUM=-YBP
YBP=-YBOD
YBOD=DUM
DUM=-THBP
THBP=-THBOD
THBOD=DUM
YEND=-YEND
THEND=-THEND
IF (I OVER .EQ. 2) RETURN
4000 CONTINUE
XJ=J1
XJ1=J2
WTMOLE(1)=1.008
WTMOLE(2)=16.
WTMOLE(3)=18.016
WTMOLE(4)=2.016
WTMOLE(5)=32.0
WTMOLE(6)=17.008
WTMOLE(7)=28.014
WTMOLE(8)=44.011
WTMOLE(9)=28.011
WTMOLE(10)=44.1
RO=1.987
CALL COEFF(5,TIN,AZ,BZ,CZ,DZ,EZ,FZ,GZ)
CPIN=(AZ+BZ*TIN+CZ*TIN**2+DZ*TIN**3+EZ*TIN**4)*RO/WTMOLE(5)
CALL COEFF(7,TIN,AZ,BZ,CZ,DZ,EZ,FZ,GZ)
CP11=(AZ+BZ*TIN+CZ*TIN**2+DZ*TIN**3+EZ*TIN**4)*RO/WTMOLE(7)
RINF=RO/WINF
CPIN=.232*CPIN+.768*CP11
GAMINF=1./(1.-RINF/CPIN)
EIN=(GAMINF-1.)*EMINF**2
PIN=1./GAMINF/EMINF**2
WRITE(6,6899)EMINF,TIN,WINF,PINF
6899 FORMAT(/ / 50X,*INFINITY CONDITIONS*/50X,*-----*/
1/40X,*MACH -----*,E13.5/40X,*TEMPERATURE (DEGREES
2 K) ----*,E13.5/40X,*MOLECULAR WEIGHT -----*,E13.5/40X
1*PRESSURE (PSI) -----*E13.5)
WRITE(6,6723)
6723 FORMAT(/ / 40X,*OUTPUT VARIABLES ARE*/40X,*NONDIMENSIONALIZED*/
140X,*AS FOLLOWS -*/40X,*X BY RTH*/40X,*Y BY RTH*/40X,*Q BY FREE S
2TREAM VELOCITY*/40X,*T BY FREE STREAM TEMPERATURE*/40X,*P BY FREE
3STREAM PRESSURE*)
IF(IEQ.EQ.0) WRITE(6,5003)
5003 FORMAT( /40X,*ALP(J) IS MASS FRACTION OF SPECIES J*)
DO 6897 I=1,NPTS
PF(I)=PF(I)*PIN
6897 CONTINUE
UINF=1716.*TIN*1.8/PIN
RHOINF=(PINF/TIN/1.8/1716.)*2116.
IF(IEQ.EQ.0) GO TO 2930
DO 2929 I=1,NPTS
2929 WF(I)=FH(PF(I),RF(I),TF(I))
2930 CONTINUE
H16=GAMINF/WINF/2.*EMINF*EMINF
H17=1./H16
63 FORMAT(8E10,0)
11 FORMAT(7E11,4)
RETURN
END

```


SUBROUTINE COEFF(I,T,A ,B ,C ,D ,E ,F ,G)

TM=1000

IF (T-1000)10,10,20

10 GO TO (15,16,13,11,12,17,14,18,19),I

11 A = 2.8460849E 00

B = 4.1932116E-03

C = -9.6119332E-06

D = 9.5122662E-09

E = -3.3093421E-12

F = -9.6725372E 02

G = -1.4117850E 00

GO TO 40

12 A = 3.7189946E 00

B = -2.5167288E-03

C = 8.5837353E-06

D = -8.2998716E-09

E = 2.7082180E-12

F = -1.0576706E 03

G = 3.9080704E 00

GO TO 40

13 A = 4.1565016E 00

B = -1.7244334E-03

C = 5.6982316E-06

D = -4.5930044E-09

E = 1.4233654E-12

F = -3.0288770E 04

G = -6.8616246E-01

GO TO 40

14 A = 3.6916148E 00

B = -1.3332552E-03

C = 2.6503100E-06

D = -9.7688341E-10

E = -9.9772234E-14

F = -1.0628336E 03

G = 2.2874980E 00

GO TO 40

15 A = 2.5000000E 00

B = 0.0

C = 0.0

D = 0.0

E = 0.0

F = 2.5470497E 04

G = -4.6001096E-01

GO TO 40

16 A = 3.0218894E 00

B = -2.1737249E-03

C = 3.7542203E-06

D = -2.9947200E-09

E = 9.0777547E-13

F = 2.9137190E 04

G = 2.6460076E 00

GO TO 40

17 A = 3.8234708E 00

B = -1.1187229E-03

C = 1.2466819E-06

D = -2.1035896E-10

E = -5.2546551E-14

F = 3.5852787E 03

G = 5.8253029E-01

GO TO 40

18 A=2.1701
R=1.0378115E-02
C=-1.0733938E-05
D=6.3459175E-09
E=-1.6280701E-12
F=-4.8352602E+04
G=1.0664388E+01
GO TO 40

19 A=3.7871332
B=-2.1709526E-03
C=5.0757337E-06
D=-3.4737726E-09
E=7.7216841E-13
F=-1.4363508E+04
G=2.6335459
GO TO 40

20 GO TO (25, 26, 23, 21, 22, 27, 24, 28, 29), I

21 A = 3.0436897E 00
B = 6.1187110E-04
C =-7.3993551E-09
D =-2.0331907E-11
E = 2.4593791E-15
F =-8.5491002E 02
G =-1.6481339E 00
GO TO 40

22 A = 3.5976129E 00
B = 7.8145603E-04
C =-2.2386670E-07
D = 4.2490159E-11
E =-3.3460204E-15
F =-1.1927918E 03
G = 3.7492659E 00
GO TO 40

23 A = 2.6707532E 00
B = 3.0317115E-03
C =-8.5351570E-07
D = 1.1790853E-10
E =-6.1973568E-15
F =-2.9888994E 04
G = 6.8838391E 00
GO TO 40

24 A = 2.3545761E 00
B = 1.5976316E-03
C =-6.2566254E-07
D = 1.1315849E-10
E =-7.6897070E-15
F =-8.9017445E+02
G = 6.3902879E 00
GO TO 40

25 A = 2.5000000E 00
B = 0.0
C = 0.0
D = 0.0
E = 0.0
F = 2.5470497E 04
G =-4.6001096E-01
GO TO 40

26 A = 2.5372567E 00
C =-8.8017921E-09
D = 5.9643621E-12

E = -5.5743608E-16
F = 2.9230007E-04
G = 4.9467942E-00
GO TO 40
27 A = 2.8895544E-00
B = 9.9835061E-04
C = -2.1879904E-07
D = 1.9802785E-11
E = -3.8452940E-16
F = 3.8811792E-03
G = 5.5597016E-00

GO TO 40
28 A = 4.4129266
B = 3.1922896E-03
C = -1.297823E-06
D = 2.4147446E-10
E = -1.6742986E-14
F = -4.8944043E+04
G = -7.2875769E-01

GO TO 40
29 A = 2.9511519
B = 1.55255767E-03
C = -6.1911411E-07
D = 1.1350336E-10
E = -7.7882732E-15
F = -1.4231827E-04
G = 6.531445

40 RETURN
END

```
SUBROUTINE ERROR(IIII)  
WRITE(6,100) IIII  
100 FORMAT(7H1ERROR=15)  
CALL EXIT  
RETURN  
END
```

```

SUBROUTINE BODL(XI,YI,THI,XL,YL,EM2,XN,YN,THN)
COMMON/SHAPE/ A1(3,2),A2(3,2),A3(3,2),XXU(3),XXL(3),XINTU,XINTL
XI=XI-XINTL
XL=XL-XINTL
ICK=1
L=3
ASL=TAN(THI)
XN=(YI-YL+XL*EM2-XI*ASL)/(EM2-ASL)
5 IF(XN.LT.XXL(3)) L=2
  IF(XN.LT.XXL(2)) L=1
  YN=A1(L,2)*XN*XN+A2(L,2)*XN+A3(L,2)
  YT=YL+(XN-XL)*EM2
  ER=(YN-YT)
  IF(ABS(ER).LT.1.E-04) GO TO 10
  ICK=ICK+1
  IF(ICK.LT.15) GO TO 3511
  WRITE(6,3512)
3512 FORMAT(* TOO MANY ITERATIONS IN BODL*)
  STOP
3511 IF(ICK.GT.2) GO TO 3513
  ER1=ER
  XSL1=XN
  XN = 1.01*XN
  L=3
  GO TO 5
3513 DUM=XSL1-ER1*(XN - XSL1)/(ER-ER1)
  ER1=ER
  XSL1=XN
  XN = DUM
  L=3
  GO TO 5
10 THN=ATAN(2.*A1(L,2)*XN+A2(L,2))
  XI=XI+XINTL
  XL=XL+XINTL
  XN=XN+XINTL
  RETURN
END

```

```

SUBROUTINE BODU(X,Y,TH)
COMMON/SHAPE/ A1(3,2),A2(3,2),A3(3,2),XXU(3),XXL(3),XINTU,XINTL
X=X-XINTU
L=3
IF (X.LT.XXU(3)) L=2
IF (X.LT.XXU(2)) L=1
Y=A1(L,1)*X+A2(L,1)*X+A3(L,1)
TH=ATAN(2.*A1(L,1)*X+A2(L,1))
X=X+XINTU
RETURN
END

```

```

SUBROUTINE COWL(OPT)
COMMON/COWL/ICOWL,MM,XM(9),YM(9),PM(9),WM(9),RHM(9),THM(9),QM(9),
1 RM(9),TM(9),GM(9),XMUM(9),EMM(9),ALPM(7,9),CPXM(9)
COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
COMMON/VAR/RHO(200),
1 EM(200),XMU(200),CPX(200),W(200),R(200),GAM(200),XMASS(200),
2 XN(200),YN(200),QN(200),TN(200),PN(200),THN(200),RHON
3 (200),EMN(200),XMUN(200),CPXN(200),WN(200),RN(200),GAMN(200),
4 XMASSN(200),ALPN(10,200),SI(10),HI(10),ERR(20),TEMP(20)
5 ,ALPDUM(10)
COMMON /SP/ NSP
COMMON/X/ X(200),Y(200),P(200),Q(200),T(200),TH(200),ALP(10,200)
XM(MM)=X(1)
YM(MM)=Y(1)
PM(MM)=PM(MM)*PIN
WM(MM)=FH(PM(MM),RM(MM),TM(MM))
DO 4385 J=1,NSP
4385 ALPDUM(J)=0.
CALL ALL(QQ,WM(MM),RHM(MM),RM(MM),GM(MM),EMM(MM),XMUM(MM),QM(MM),
1 TM(MM),PM(MM),ALPDUM)
BET=(THM(MM)-OPT*XMUM(MM)+TH(1))*1.1
ITT=1
IF AN=MM-3
3 IT=1
II=MM-1
VT=QM(MM)*COS(BET-THM(MM))
U1=QM(MM)*SIN(BET-THM(MM))
U1=ABS(U1)
GM1=GM(MM)-1.
GP1=GM(MM)+1.
XM1=EMM(MM)*SIN(BET-THM(MM))
XMS=RHM(MM)*U1
IF (ITT.EQ.1) UM=U1*(GM1*XM1*XM1+2.)/GP1/XM1/XM1
7 RH2=XMS/UM
PM(II)=XMS*(U1-UM)+PM(MM)
V1=QM(MM)*QM(MM)
V2=VT*VT+UM*UM
WM(II)=WM(MM)+(V1-V2)/2.
RM(II)=RM(MM)
RHM(II)=RHEQ(WM(II),PM(II),RM(II),TM(II))
ER=RH2-RHM(II)
IF (ABS(ER).LT.1.E-04) GO TO 9
ITT=ITT+1
IF (ITT.GT.10) GO TO 100
IF (ITT.GT.2) GO TO 11
ER2=ER
U2=UM
UM=UM*.99
GO TO 7
100 WRITE(6,200)
200 FORMAT(* ERROR IN HUGONIOT LOOP IN COWL*)
STOP
11 DUM2=U2-ER2*(UM-U2)/(ER-ER2)
ER2=ER
U2=UM
UM=DUM2
GO TO 7
9 THM(II)=BET-ATAN(UM/VT)
QM(II)=SQRT(V2)

```

```

XM(II)=XM(MM)
YM(II)=YM(MM)
GM(II)=FGAM(TM(II),PM(II),RM(II))
EMM(II)=QM(II)/SQRT(GM(II)*PM(II)/RHM(II))
XMUM(II)=ATAN(1./SQRT(EMM(II)**2-1.))
THM(II-1)=THM(II)
QM(II-1)=QM(II)
PM(II-1)=PM(II)
WM(II-1)=WM(II)
RHM(II-1)=RHM(II)
RM(II-1)=RM(II)
TM(II-1)=TM(II)
XM(II-1)=XM(II)
YM(II-1)=YM(II)
GM(II-1)=GM(II)
EMM(II-1)=EMM(II)
XMUM(II-1)=XMUM(II)
DP=(P(1)-PM(II))/FLOAT(IFAN-1)
II=1

```

```

X M(II)=X (1)
Y M(II)=Y (1)
W M(II)=W (1)
P M(II)=P (1)
RH M(II)=RHO(1)
G M(II)=GAM(1)
Q M(II)=Q (1)
TH M(II)=TH (1)
XMUM(II)=XMU(1)
T M(II)=T (1)
R M(II)=R (1)
EM M(II)=EM (1)
DO 12 LL=2,IFAN
N=LL

```

```

KK=N-1
XM(N)=XM(KK)
YM(N)=YM(KK)
PM(N)=PM(KK)-DP
ALNR=ALOG(PM(N)/PM(KK))
RHM(N)=ALOG(RHM(KK))+ALNR/GM(KK)
RHM(N)=EXP(RHM(N))
G=2.*GM(KK)/(GM(KK)-1.)
QM(N)=SQRT(QM(KK)*QM(KK)-G*(PM(N)/RHM(N)-PM(KK)/RHM(KK)))
WM(N)=WM(KK)+(QM(KK)*QM(KK)-QM(N)*QM(N))/2.
RM(N)=RM(KK)
TM(N)=FT(PM(N),RM(N),WM(N))
GM(N)=FGAM(TM(N),PM(N),RM(N))
EMM(N)=(QM(N)/SQRT(GM(N)*PM(N)/RHM(N)))
XMUM(N)=ASIN(1./EMM(N))
A1=.5*(GM(N)/SIN(XMUM(N))/COS(XMUM(N))+GM(KK)/SIN(XMUM(KK))/COS
1(XMUM(KK)))
THM(N)=THM(KK)+OPT*ALNR/A1

```

```

12 CONTINUE
ER4=THM(IFAN)-THM(IFAN+1)
IF(ABS(ER4).LT.1.E-04) GO TO 15
ITT=ITT+1
IF(ITT.GT.15) GO TO 102
IF(ITT.GT.2) GO TO 14
ER1=ER4
BET1=BET
BET=BET+.02

```



```
GO TO 3
102 WRITE(6,203)
203 FORMAT(* ERROR IN BETA LOOP IN COWL*)
STOP
14 DUM1=BET1-ER1*(BET-BET1)/(ER4-ER1)
  ER1=ER4
  BET1=BET
  BET=DUM1
  GO TO 3
15 CONTINUE
  RETURN
  END
```

```

SUBROUTINE COWLO(I,THM,EM,BET,PMM)
COMMON/FVAR/
1RHOF(200),CPXF(200),EMF(200),XMUF(200),WF(200),RF(200),GAMF(200),
2XMASSF(200),HF(200),SF(200),ALPD(10),
3THETA(20)
COMMON/XF/XF(200),YF(200),PF(200),QF(200),TF(200),THF(200),ALPF(
110,200)
COMMON/D/ GAMINF,EMINF,RINF,WINF
COMMON/C1/ EMC1,TC1,QC1
J=I+1
BET=THF(I)-XMUF(I)
BET=BET-.1*ABS(BET)
ITT=1
3 CONTINUE
CALL SHOCK(BET,QF(I),THF(I),GAMF(I),EMF(I),RHOF(I),PF(I),WF(I),
1RF(I),QF(J),THF(J),GAMF(J),EMF(J),RHOF(J),PF(J),WF(J),RF(J),
1TF(J),XMUF(J),-1.)
P2=PF(J)*GAMINF*EMINF*EMINF
P2=P2/PMM
TH2=THF(J)
CALL PM(P2,THM,EM,TH2T,EM3,-1)
ER4=TH2T-TH2
IF(ABS(ER4).LT.1.E-04) GO TO 15
ITT=ITT+1
IF(ITT.GT.15) GO TO 102
IF(ITT.GT.2) GO TO 14
ER1=ER4
BET1=BET
BET=BET+.02
GO TO 3
102 WRITE(6,203)
203 FORMAT(4 ERROR IN BETA LOOP IN COWLO*)
STOP
14 DUM1=BET1-ER1*(BET-BET1)/(ER4-ER1)
ER1=ER4
BET1=BET
BET=DUM1
GO TO 3
15 CONTINUE
DO 300 JJ=1,7
300 ALPF(JJ,J)=ALPF(JJ,I)
XF(J)=XF(I)
YF(J)=YF(I)
EMC1=EM3
DUM1=1.+(GAMINF-1.)/2.*EMINF*EMINF
DUM2=1.+(GAMINF-1.)/2.*EM3*EM3
TC1=DUM1/DUM2
QC1=EM3/EMINF*SQRT(TC1)
RETURN
END

```

```

SUBROUTINE SHOCK(BET,Q1,TH1,G1,EM1,RH1,P1,H1,PHI1,Q2,TH2,G2,EM2,
1RH2,P2,H2,PHI2,T2,XMU2,FSH)

```

```

IT=1

```

```

VT=Q1*COS(BET-TH1)

```

```

U1=ABS(Q1*SIN(BET-TH1))

```

```

GM1=G1-1.

```

```

GP1=G1+1.

```

```

XM1=EM1*SIN(BET-TH1)

```

```

XMS=RH1*U1

```

```

IF(IT.EQ.1)UM=U1*(GM1*XM1*XM1+2.)/GP1/XM1/XM1

```

```

7 RH2=XMS/UM

```

```

P2=XMS*(U1-UM)+P1

```

```

V1=Q1*Q1

```

```

V2=VT*VT+UM*UM

```

```

H2=H1+(V1-V2)/2.

```

```

PHI2=PHI1

```

```

RH2T=RH2*Q2,P2,PHI2,T2)

```

```

ER=RH2-RH2T

```

```

IF(ABS(ER/RH1).LT.1.E-03)GO TO 9

```

```

IT=IT+1

```

```

IF(IT.GT.15)GO TO 100

```

```

IF(IT.GT.2)GO TO 11

```

```

ER2=ER

```

```

U2=UM

```

```

UM=UM*.99

```

```

GO TO 7

```

```

100 WRITE(6,200)

```

```

200 FORMAT(* ERROR IN HUGONIOT LOOP IN SHOCK*)

```

```

STOP

```

```

11 DUM2=U2-ER2*(UM-U2)/(ER-ER2)

```

```

ER2=ER

```

```

U2=UM

```

```

UM=DUM2

```

```

GO TO 7

```

```

9 IF(FSH.GT.0.)TH2=BET-ATAN(UM/VT)

```

```

IF(FSH.LT.0.)TH2=ATAN(UM/VT)+BET

```

```

Q2=SQRT(V2)

```

```

G2=GAM(T2,P2,PHI2)

```

```

EM2=Q2/SQRT(G2*P2/RH2)

```

```

XMU2=ATAN(1./SQRT(EM2*EM2-1.))

```

```

RETURN

```

```

END

```

```

SUBROUTINE SHOCPT( IS,M,BET,BETN,A,B)
COMMON /VAR/ RHO(200),
1 EM(200), XMU(200), CPX(200), W(200), R(200), GAM(200), XMASS(200),
2 XN(200), YN(200), QN(200), TN(200), PN(200), THN(200), RHON
3 (200), EMN(200), XMUN(200), CPXN(200), WNN(200), RNN(200), GAMN(200),
4 XMASSN(200), ALPN(10,200), SI(10), HI(10), ERR(20), TEMP(20)
5 ,ALPDUM(10)
COMMON /X/ X(200), Y(200), P(200), Q(200), T(200), TH(200), ALP(10,200)
COMMON /ETX/ XJ, XJ1, NPIS, ID, IREFL, ICHEM, IPUNCH, IDESGN, IR, NXX, XBP,
1 YBP, THBP, RAD, XBOB, YBOB, THBOB, RADB, XEND, TEND, RTH, YEXIT, THST, TEST,
1 IREFL, Y0, RADB2, RRAD(20), NSTAR, YNOZ, EIN, PEN, H16, H17
IF (B.EQ.0.) BETN=BET+(THN(IS-1)+XMUN(IS-1)-TH(M-1)-XMU(M-1))
I=IS
J=IS+1
L=IS
ITT=1
3 CALL SHOCK(BETN, QN(I), THN(I), GAMN(I), EMN(I), RHON(I), PN(I), WN(I),
1 RN(I), QN(J), THN(J), GAMN(J), EMN(J), RHON(J), PN(J), WN(J), RN(J), TN(J),
1 XMUN(J), 1.)
EM1=XM1(.5,.5, THN(J), XMUN(J), TH(M), XMU(M))
EM2=XM2(.5,.5, TH(M), XMU(M), TH(M+1), XMU(M+1))
YDUM=(EM1*Y(M)-EM2*YN(L)+EM1*EM2*(XN(L)-X(M)))/(EM1-EM2)
RAT=(YDUM-Y(M))/(Y(M+1)-Y(M))
Y2=YDUM
IF (IS.EQ.2.AND.M.EQ.2) RAT=0.
IF (IS.EQ.2.AND.M.EQ.2) Y2=Y(M)
X2=X(M)+RAT*(X(M+1)-X(M))
CALL PANDW(P(M), P(M+1), RAT, P2, DUM1, DUM2, DUM3, DUM4, DUM5, DUM6, DUM7
1,1)
TH2=TH(M)+RAT*(TH(M+1)-TH(M))
XMU2=XMU(M)+RAT*(XMU(M+1)-XMU(M))
GAM2=GAM(M)+RAT*(GAM(M+1)-GAM(M))
A1=F1(A,B,XMU2,GAM2,P2,XMUN(J),GAMN(J),PN(J))
A2=F2(A,B,1,XJ,XJ1,X2,Y2,TH2,XMU2,XN(J),YN(J),THN(J),XMUN(J))
DUM1=A2*(XN(J)-X2)
DUM=(TH2-THN(J)-DUM1)/A1
PTEST=P2*EXP(DUM)
ER4=(PTEST-PN(J))/P(M)
IF (ABS(ER4).LT.1.E-04) GO TO 15
ITT=ITT+1
IF (ITT.GT.15) GO TO 102
IF (ITT.GT.2) GO TO 14
ER1=ER4
BET1=BETN
BETN=BETN+.02
GO TO 3.
102 WRITE(6,203)
203 FORMAT(* ERROR IN BETA LOOP IN SHOCPT*)
STOP
14 DUM1=BET1-ER1*(BETN-BET1)/(ER4-ER1)
ER1=ER4
BET1=BETN
BETN=DUM1
GO TO 3
15 CONTINUE
XN(J)=XN(I)
YN(J)=YN(I)
DO 300 JJ=1,7
300 ALPN(JJ,J)=ALPN(JJ,I)

```

RE TURN
END

```

SUBROUTINE PANDW (P1,P2,RAT,POUT,W1,W2,Q1,Q2,Q3,WOUT,IEQ,I)
DUM1=ALOG(P1)
DUM2=ALOG(P2)
POUT=DUM1+RAT*(DUM2-DUM1)
POUT=EXP(POUT)
IF (I.EQ.1) RETURN
WT1=W1+Q1*Q1/2.
WT2=W2+Q2*Q2/2.
WT3=WT1+RAT*(WT2-WT1)
WOUT=W1+RAT*(W2-W1)
IF (IEQ.EQ.1) WOUT=WT3-Q3*Q3/2.
RETURN
END

```

```

SUBROUTINE DRTEST(XN,YN,EM1,BET,IDROP,L,M)
COMMON/X/ X(200),Y(200),P(200),Q(200),T(200),TH(200),ALP(10,200)
EM2=TAN(BET)
XNT=(Y(M)-Y(M+L))-EM1*X(M)+EM2*X(M+L)/(EM2-EM1)
YNT=Y(M)+EM1*(XNT-X(M))
DISNOR=SQRT((XN-X(M))**2+(YN-Y(M))**2)
DISEX=SQRT((XNT-X(M))**2+(YNT-Y(M))**2)
IF((DISEX-DISNOR)/DISEX.LT..1) IDROP=1
RETURN
END

```

```

SUBROUTINE PM(P, TH1, XM1, TH2, XM2, IS)
COMMON/D/ GAMINF,EMINF,RINF,WINF
G=GAMINF
GM1=G-1.
GP1=G+1.
DUM=1.+GM1/2.*XM1*XM1
P=P*(GM1/G)
XM2=(DUM/P-1.)*2./GM1
XM2=SQRT(XM2)
GX=SQRT(GP1/GM1)
DUM1=SQRT(XM1*XM1-1.)
DUM2=SQRT(XM2*XM2-1.)
DTH=GX*(ATAN(DUM2/GX)-ATAN(DUM1/GX))+ATAN(DUM1)-ATAN(DUM2)
TH2=TH1+FLOAT(IS)*DTH
RETURN
END

```



```

SUBROUTINE ALL (CPX,W,RHO,R,GAM,EM,XMU,Q,T,P,ALP1)
COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
COMMON/A/ TIN,CPIN,RO
COMMON/D/ GAMINF,EMINF,RINF,WINF
COMMON/B/ WTMOLE
COMMON /SP/ NSP
COMMON /ENTH/ HX
DIMENSION H1(10),CP1(10),DCP1(10),ALP1(10)
DIMENSION WTMOLE(10)
CPX=0.
IF(IEQ.EQ.1) GO TO 69
W=0.
HX=0.
CALL THERMO(T,H1,CP1,DCP1)
DO 10 J=1,NSP
CPX=CPX+ALP1(J)*CP1(J)
HX=HX+ALP1(J)*H1
10 W=W+ALP1(J)/WTMOLE(J)
W=1./W
RHO=GAMINF*EMINF**2*W*P/T/WINF
R=RO/W
GAM=CPX/(CPX-R/CPIN)
EM=Q*EMINF*SQRT(GAMINF*RINF/GAM/R/T)
XMU=ATAN(1./SQRT(EM**2-1.))
RETURN
69 RHO=RHEQ(W,P,R,T)
GAM=FGAM(T,P,R)
EM=Q/SQRT(GAM*P/RHO)
XMU=ATAN(1./SQRT(EM*EM-1.))
RETURN
END

```

```

SUBROUTINE THERMO(TI,H,CP,DCP)
COMMON /SP/ NSP
COMMON /A/ TIN,CPIN,R0
COMMON /B/ WTMOLE
DIMENSION WTMOLE(10)
DIMENSION H(10),CP(10),DCP(10)
T=TI*TIN
C1=R0/CPIN
C2=C1/TIN
C3=C1*TIN
N=NSP
DO 10 J=1,N
H1=C2/WTMOLE(J)
H2=C1/WTMOLE(J)
H3=C3/WTMOLE(J)
CALL COEFF(J,T,A,B,C,D,E,F,G)
H(J)=T*(A+T*(B/2.+T*(C/3.+T*(D/4.+E/5.*T))))+F
H(J)=H(J)*H1
CP(J)=A+T*(B+T*(C+T*(D+E*T)))
CP(J)=CP(J)*H2
DCP(J)=B+T*(2.*C+T*(3.*D+4.*E*T))
DCP(J)=DCP(J)*H3
10 CONTINUE
RETURN
END

```

```

FUNCTION FT(P1,F,H5)
COMMON/IPP/IPP
COMMON /THE/ A1,A2,A3,A4,A5,A6,XMM1
COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
COMMON/A/ TIN,CPIN,R0
DATA I63/0/
IFLAG=0
IHOLD=0
P=P1/PIN*PINF*1.01325E+05
H=H5*UINF/10.7639/1.E+06
F2=F*F
A10=ALOG(P)/2.3-5.
Z9=.125*A10*A10 - .275*A10
IT=1
IF (I63.EQ.1) GO TO 1000
I63=1
T=1500.
T0=1500.
IF (F.GE.0.) GO TO 120
T=600.
T0=T
1000 CONTINUE
IF (F.LT.0.) GO TO 400
GO TO 120
50 E0=(H-H1)/H
IF (ABS(E0).LT.1.E-04) GO TO 340
500 T=T0*1.1
502 IT=2
IF (F.LT.0.) GO TO 400
GO TO 120
100 E1=(H-H1)/H
IF (ABS(E1).LT.1.E-04) GO TO 340
IT=IT+1
IF (IT.LT.21) GO TO 10
IF (ABS(T-2000.).LT.10.) GO TO 830
IF (IHOLD.EQ.0) GO TO 800
WRITE(6,831) P1,H5,T
831 FORMAT(* ERROR IN FT*/ * P1 = *E13.5,5X,*H1 = *E13.5,5X,*T = *E13.5
1)
STOP
800 T=THOLD
T0=T
H=HHOLD
IT=1
IHOLD=1
IF (T.LE.2000.) IHOLD=-1
GO TO 1000
830 IF (IFLAG.EQ.1) GO TO 504
IFLAG=1
T0=2000.
T=2000.
IF (F.LT.0.) GO TO 400
GO TO 120
504 WRITE(6,11) E1
11 FORMAT(* TEMPERATURE IN FT SET TO 2000 - ERROR = *E13.5)
GO TO 340
10 T9=T0-E0*(T-T0)/(E1-E0)
505 E0=E1
T0=T

```

```

T=T9
IF (F.LT.0.) GO TO 400
120 A=1.E-07*(-.1042*F2 +.8242*F+.987)
B=.001*(.01167*F2 +.1503*F+.938)
C=-.0284*F2 +.6731*F+.4293
IF (F.LE.1.) GO TO 190
A=1.E-07*(1.787*F2 -5.48*F+5.4)
B=.001*(-.1867*F2 +1.11*F+.176)
C=-.0933*F2 +3.975*F-2.808
190 IF (T.LE.2000..AND.IHOLD.NE.1) GO TO 290
A=.000001*(1.792*F2 +.3983*F+.31)
B=.001*(-9.05*F2 -.07917*F+.245)
C=10.86*F2 -.1183*F+.97
IF (F.LE.1.) GO TO 290
A=.000001*(4.81*F2 -13.9*F+11.59)
B=.001*(-23.08*F2 +66.82*F-52.61)
C=27.05*F2 -73.73*F+58.39
290 H1=A*T*T+B*T+C
IF (T.LE.2000..AND.IHOLD.NE.1) GO TO 370
H1=H1*(1.+(1.+F)*(T/2000.-1.)*Z9)
370 CONTINUE
GO TO 350
400 T2=T*T
T3=T2*T
T4=T3*T
T5=T4*T
IF (F.LT.-1.5) GO TO 450
XMM1=16.043
A1=4.2497678
A2=-6.9126562E-03
A3=3.1602134E-05
A4=-2.9715432E-08
A5=9.5103580E-12
A6=-1.0186632E+04
GO TO 460
450 CONTINUE
A1=1.1202436
A2=1.3905716E-02
A3=2.6568374E-06
A4=-1.1560272E-08
A5=5.2386929E-12
A6=5.3328896E+03
XMM1=28.054
460 H1=A1*T+A2*T2/2.+A3*T3/3.+A4*T4/4.+A5*T5+A6
H1=H1*8314./XMM1/1.E+06
350 IF (IT.EQ.1) GO TO 50
GO TO 100
340 T0=T
FT=T/TIN
THOLD=T
MHOLD=H
RETURN
END

```

```

FUNCTION FR(P1,F,T1)
COMMON /THE/ A1,A2,A3,A4,A5,A6,XMM1
COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
COMMON/A/ TIN,CPIN,RO
P=P1/PIN*PINF*1.01325E+05
T=T1*TIN
F2=F*F
IF(F.LT.0.) GO TO 400
IF(T.GT.2000.) GO TO 190
IF(F.GT.1.) GO TO 191
120 A=1.E-07*(-.1042*F2 +.8242*F+.987)
B=.001*(.01167*F2 +.1503*F+.938)
C=-.0284*F2 +.6731*F+.4293
GO TO 290
191 A=1.E-07*(1.787*F2 -5.48*F+.54)
B=.001*(-.1867*F2 +1.11*F+.176)
C=-.0933*F2 +3.975*F-2.808
GO TO 290
190 IF(F.GT.1.) GO TO 192
A=.000001*(1.792*F2 +.3983*F+.31)
B=.001*(-9.05*F2 -.07917*F+.245)
C=10.86*F2 -.1183*F+.97
GO TO 290
192 A=.000001*(4.81*F2 -13.9*F+11.59)
B=.001*(-23.08*F2 +66.82*F-52.61)
C=27.05*F2 -73.73*F+58.39
290 H1=A*T+B*T+C
IF(T.LE.2000.) GO TO 370
A10=ALOG(P)/2.3-5.
Z9=.125*A10*A10 -.275*A10
H1=H1*(1.+(1.+F)*(T/2000.-1.)*Z9)
370 H1=H1*1.E+06
GO TO 340
400 T2=T*T
T3=T2*T
T4=T3*T
T5=T4*T
H1=A1*T+A2*T2/2.+A3*T3/3.+A4*T4/4.+A5*T5+A6
H1=H1*8314./XMM1
340 CONTINUE
FH=H1*10.7639/UINF
RETURN
END
FUNCTION FGAM(T1,P1,F)
COMMON /THE/ A1,A2,A3,A4,A5,A6,XMM1
COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
COMMON/A/ TIN,CPIN,RO
T=T1*TIN
T2=T*T
P=P1/PIN*PINF*1.01325E+05
XM=0.
IF(F.LT.0.) GO TO 550
IF(T.LE.1000.) GO TO 440
XM=-2.15E-08*T2 +.000091*T-.0695
440 XN=4.E-09*T2 -.00002*T-.019
IF(F.LE.1.) GO TO 470
XN=.0339*SQR(T)-.000391*T-.681
470 G=-1.833E-07*T2 +.000075*T+1.367
IF(T.LT.500.) GO TO 520

```

G=2.E-08*T2 -.000138*T+1.423

IF (T.L1.2000.) GO TO 520

G=7.267E-08*T2 -.000457*T+1.85

520 G=G+XM*(ALOG(P)/2.3-5.)+XN*(F-1.)
GO TO 530

550 T3=T2*T

T4=T3*T

CP=A1+A2*T+A3*T2+A4*T3+A5*T4

G=CP*(CP-1.)

530 CONTINUE

FGAM=G

RETURN

END

```

FUNCTION RHEQ(H,P1,F,T)
COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
COMMON/A/ TIN,CPIN,RO
T1=FT(P1,F,H)
T=T1*TIN
P=P1/PIN*PINF*1.01325E+05
IF (F.LT.0.) GO TO 2260
FNM=1.53*F*F-5.895*F+28.965
FNN=1.6*F*F-10.6*F+33.6
IF (T.GT.2000.) GO TO 2030
XM=FNM
IF (F.LT.1.) GO TO 2160
XM=FNN
GO TO 2160
2030 FF=F*F
A=-2.3*FF+4.01*F+1.736
B=8.61*F-15.42*F-6.66
C=-16.88*FF+33.21*F+14.58
XN=-.4375*FF+.0625*F+2.08
D=A*(ALOG(P)/2.3)**1.5+B*(ALOG(P)/2.3)+C
XM=FNM-D*((T-2000.)/1000.)**XN
IF (F.LT.1.) GO TO 2160
A=-.822*FF+2.363*F+1.905
B=2.76*FF-7.56*F-8.68
C=-3.6*FF+7.36*F+27.15
XN=-.47*FF+1.825*F+.35
D=A*(ALOG(P)/2.3)**1.5+B*(ALOG(P)/2.3)+C
XM=FNN-D*((T-2000.)/1000.)**XN
GO TO 2160
2260 KF=F-.5
IF (KF.EQ.-1) XM=16.043
IF (KF.EQ.-2) XM=28.054
2160 RHEQ=P*XM/T/8314.3*6.2428E-02/32.174
T=T/TIN
RHEQ=RHEQ/RHOINF
RETURN
END

```

```
FUNCTION XM1 (ALPHA,BETA,TA,XA,TC,XC)  
XM1=ALPHA*TAN(TA+XA)  
IF (BETA.GT.0.) XM1=XM1+BETA*TAN(TC+XC)  
RETURN  
END
```



```
FUNCTION XM2 (AL, B, TA, XA, TC, XC)  
XM2=AL*TAN(TA-XA)  
IF (B.GT.0.)XM2=XM2+B*TAN(TC-XC)  
RETURN  
END
```

```
FUNCTION XM3(A,B,TD,TC)  
XM3=A*TAN(TD)  
IF(B.GT.0.0)XM3=XM3+B*TAN(TC)  
RETURN  
END
```

```
FUNCTION F1(A, B, XMU1, GAM1, P1, XMU2,  
1GAM2, P2)  
F1=SIN(XMU1)*COS(XMU1)/GAM1  
IF (B.GT.0.0)F1=(F1+SIN(XMU2)*  
1COS(XMU2)/GAM2 )/2.  
RETURN  
END
```

```

FUNCTION F2(A,B,OPT,XJ,XJ1,X,Y,TH,XMU,XN,YN,THN,XMUN)
F21=0.
IF(XJ.EQ.0.) GO TO 15
F21=A*SIN(TH)*SIN(XMU)/COS(TH+OPT*XMU)/Y
IF(B.GT.0.) F21=F21+B*SIN(THN)*SIN(XMUN)/COS(THN+OPT*XMUN)/YN
15 F22=0.
IF(XJ1.EQ.0.) GO TO 10
F22=A*COS(TH)*SIN(XMU)/COS(TH+OPT*XMU)
IF(B.GT.0.) F22=F22+B*COS(THN)*SIN(XMUN)/COS(THN+OPT*XMUN)
10 F2=F21+F22
RETURN
END

```

```

SUBROUTINE XMASSS(RATM,NPTS)
COMMON/FVAR/
1RHOF(200),CPXF(200),EMF(200),XMU(200),WF(200),RF(200),GAMF(200),
2XMASSF(200),HF(200),SF(200),ALPD(10),
3THETA(20)
COMMON/XF/XF(200),YF(200),PF(200),QF(200),TF(200),THF(200),ALPF(
110,200)
DO 170 I=1,NPTS
CALL FM(FM1,EMF(I),GAMF(I))
FM2=FM1/RATM
ITM=1
EMT=RATM*EMF(I)
197 CONTINUE
CALL FM(FMT,EMT,GAMF(I))
ERM=(FM2-FMT)/FM2
IF(ABS(ERM).LT.1.E-03)GO TO 171
DUMD=1./RATM
ITM=ITM+1
IF(ITM.GT.15)GO TO 2
IF(ITM.GT.2)GO TO 1
EMT1=EMT
ERM1=ERM
EMT=EMT*DUMD
GO TO 197
1 DUM=EMT1-ERM1*(EMT-EMT1)/(ERM-ERM1)
EMT1=EMT
ERM1=ERM
EMT=DUM
GO TO 197
2 WRITE(6,3)
3 FORMAT(* ERROR IN ITERATION LOOP IN XMASSS*)
STOP
171 CONTINUE
DUM=SQRT((GAMF(I)+1.)/(GAMF(I)-1.))
ETSQ=SQRT(EMT*EMT-1.)
ESQ=SQRT(EMF(I)*EMF(I)-1.)
XNU2=DUM*ATAN(ETSQ/DUM)-ATAN(ETSQ)
XNU1=DUM*ATAN(ESQ/DUM)-ATAN(ESQ)
DNU=XNU2-XNU1
CALL PHI(DNU,I)
170 CONTINUE
RETURN
END

```

```
SUBROUTINE FM(FMC,XM,G)
FMC=XM/(1.+(G-1.)/2.*XM**2)**((G+1.)/2./(G-1.))
RETURN
END
```

```

SUBROUTINE PM1(DNU,J6)
COMMON/ FVAR/
1 RHOF(200),CPXF(200),EMF(200),XNUF(200),WF(200),RF(200),GAMF(200),
2 XMASSF(200),
      HF(200),SF(200),ALPD(10),
3 THETA(20)
COMMON/XF/XF(200),YF(200),PF(200),QF(200),TF(200),THF(200),ALPF(
1 10,200)
DTH=2./57.3
IF AN=DNU/DTH
IF (DTH.GE.DNU) DTH=DNU
IF (DTH.EQ.DNU) IF AN=1
P1=PF(J6)
T1=TF(J6)
EM1=EMF(J6)
H1=WF(J6)
G1=GAMF(J6)
RH1=RHOF(J6)
PHI1=RF(J6)
U1=QF(J6)
U1=U1*U1
HT=H1+U1/2.
P1=ALOG(P1)
XNU=0.
XNU1=0.
DO 10 I=1,IFAN
IF (I.EQ. IFAN) DTH=DNU-XNU
XMU1=ASIN(1./EM1)
B1=G1*EM1/COS(XMU1)
P2=-B1*DTH+P1
RH2=(P2-P1)/G1
RH2=RH1*EXP(RH2)
P2P=EXP(P2)
P1P=EXP(P1)
U2=U1-2.*G1/(G1-1.)*(P2P/RH2-P1P/RH1)
H2=HT-U2/2.
T2=FT(P2P,PHI1,H2)
G2=FGAM(H2,P2P,PHI1)
A2=G2*P2P/RH2
EM2=SQRT(U2/A2)
XNU=XNU1+DTH
XNU1=XNU
P1=P2
T1=T2
G1=G2
EM1=EM2
U1=U2
RH1=RH2
10 CONTINUE
P2=EXP(P2)
U2=SQRT(U2)
P F(J6)=P 2
T F(J6)=T 2
GAMF(J6)=G 2
EM F(J6)=EM2
Q F(J6)=U 2
RHOF(J6)=RH2
W F(J6)=H 2
RETURN
END

```